Technical Series KM-71

95¢
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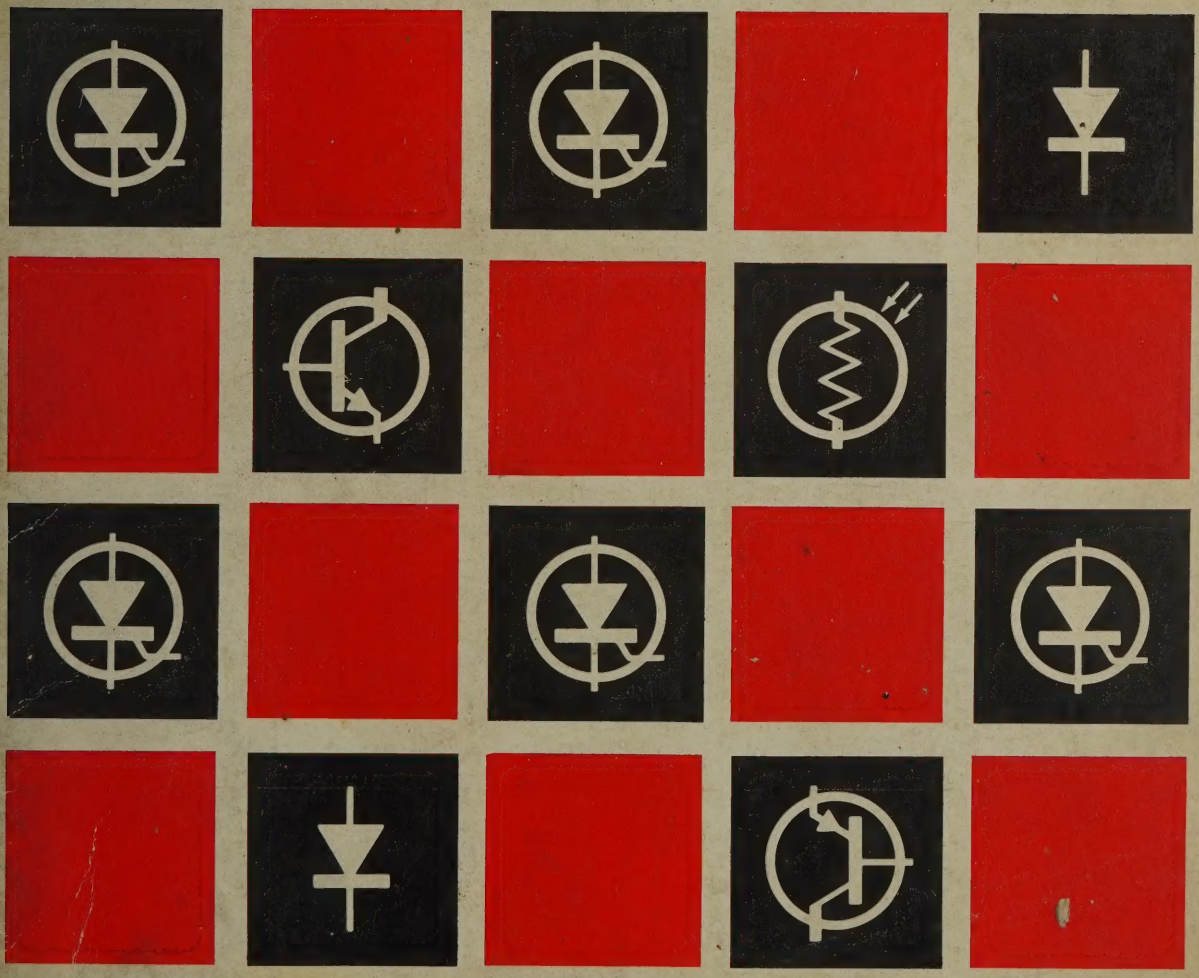
RCA SILICON CONTROLLED RECTIFIER
Experimenter's Manual



RADIO CORPORATION OF AMERICA
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RCA SILICON CONTROLLED RECTIFIER Experimenter's Manual

THE silicon controlled rectifier (SCR), a solid-state device which has been used extensively in recent years for switching, rectifying and control at 120-volt and 240-volt levels, is now available in an inexpensive kit that enables experimenters who may not be too familiar with solid-state circuits and components to build a large number of practical and interesting control circuits. This Manual presents twenty-four such circuits. The operation of each circuit is described, and schematic diagrams and photographs are shown to aid in construction. Also included are brief descriptions of the solid-state components used in the circuits (rectifiers, transistors, SCR's) and a short section on troubleshooting.

THIS Manual is intended for use with the **RCA Silicon Controlled Rectifier Experimenter's Kit KD2105.** This kit includes one silicon controlled rectifier, five rectifiers, and two transistors. The thermistors and photocells used in the heat-operated and light-operated circuits are available in **RCA Add-on Heat-Sensor Experimenter's Kit KD2110** and **RCA Add-On Light-Sensor Experimenter's Kit KD2106,** respectively.

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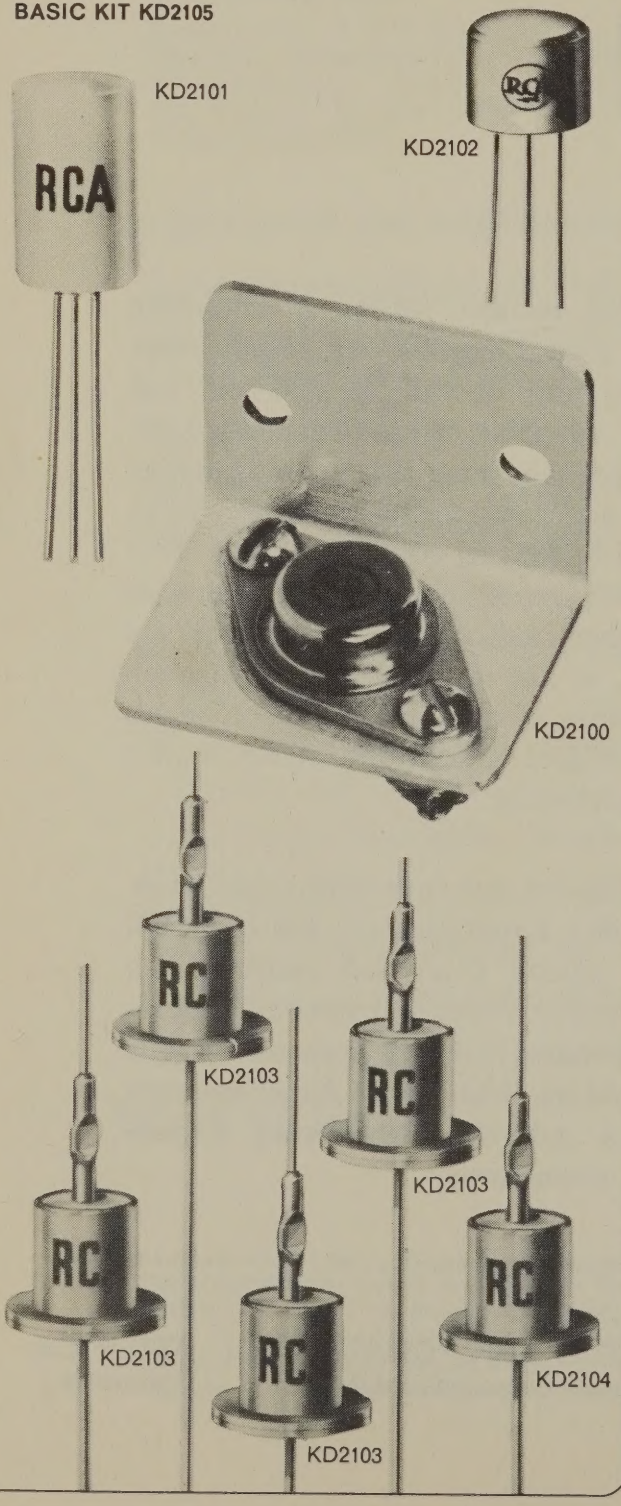
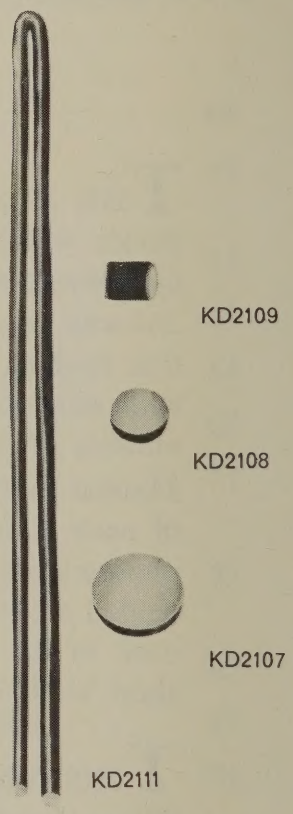
RCA KIT COMPLEMENTS

BASIC KIT KD2105



HEAT SENSOR KIT KD2110



LIGHT SENSOR KIT KD2106

Theory and Operation of Solid-State Electron Devices

IN this section, a brief introduction to the theory and operation of solid-state electron devices is given. From this material, the reader will be able to obtain a good basic understanding of solid-state devices, the nature of the semiconductor materials used in them, and how silicon rectifiers, transistors, and silicon controlled rectifiers operate.

SEMICONDUCTOR MATERIALS

In solid-state electron devices, electron flow takes place within a solid material that has semiconductor properties. Semiconductor materials have an electrical conductivity greater than that of insulators but less than that of conductors. The materials most often used in such devices are germanium and silicon. Although the conductivity of pure germanium is approximately 1000 times that of pure silicon, silicon can be operated at much higher temperatures and voltages without damage to the crystal structure. The conductivity of both materials can be increased and controlled by the addition of small amounts of other elements known as "dopants." The use of different types of dopants produces either n-type material, which has excess electrons, or p-type material, which has a shortage of electrons, or "holes," in its crystal structure.

P-N JUNCTIONS

When n-type and p-type materials are formed in one unit, as shown in Fig. 1, an interaction takes place in which some of the excess electrons from the n-type material diffuse across the junction to fill the "holes" in the p-type material. This interaction creates a small space-charge region (often called the transition region or depletion layer) in the immediate vicinity of the junction. The p-type material in this region acquires a slight negative charge as a result of the addition of electrons; conversely, the n-type material acquires a slight positive charge

as a result of the loss of excess electrons. The total effect is that of an imaginary battery connected across the junction having the polarity shown in Fig. 1. In the absence of external circuits and voltages, the potential gradient across the space-charge region discourages further diffusion across the p-n junction because

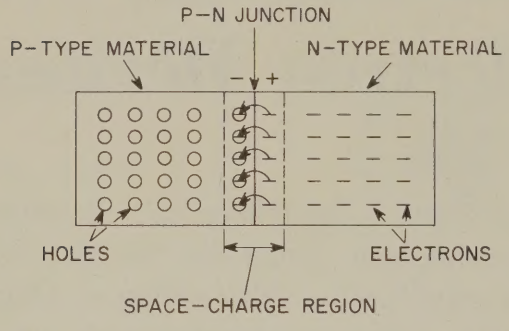


Fig. 1 — Interaction of holes and electrons at p-n junction.

electrons from the n-type material are repelled by the negative charge acquired by the p-type material at the junction. In effect, therefore, this potential gradient (or energy barrier, as it is sometimes called) prevents total interaction between the two types of materials and thus preserves the differences in their characteristics.

CURRENT FLOW

When an external battery is connected across the p-n junction, the amount of current that flows is determined by the polarity of the applied voltage and its effect on the space-charge region. Fig. 2a shows the battery connected to produce a reverse bias. This connection effectively increases the width of the space-charge region, and the potential gradient increases until it approaches the potential of the external battery; current flow is then extremely small. Under the forward-bias condition shown in Fig. 2b, the space-charge region becomes effectively narrower, and the energy barrier decreases to a very low value; electrons then continue to flow as long as the forward bias is applied.

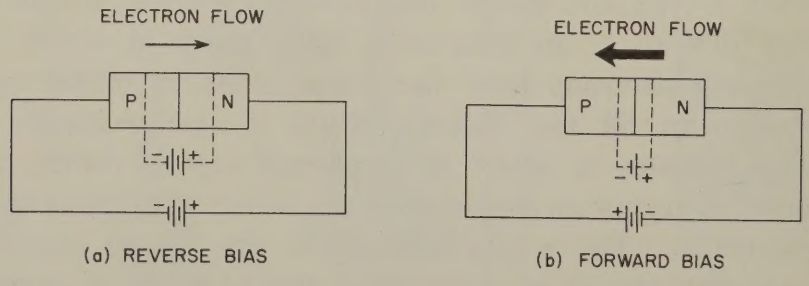


Fig. 2 — Electron current flow in biased p-n junctions.

SILICON RECTIFIERS

Structurally, the silicon rectifier, which is a semiconductor diode, is basically a p-n junction; its schematic symbol is shown in Fig. 3. Rectifiers of this type can be operated at ambient temperatures up to 100°C and at current levels as high as 400 amperes, with voltage levels as high as 1300 volts. Because of their high forward-to-reverse current ratios, they can achieve rectification efficiencies greater than 99 per cent. When properly used, they have excellent life characteristics that are little affected by aging, moisture, or temperature. They can, however, be easily damaged by sudden rises in junction temperature caused by either surges of high currents or excessive ambient-temperature conditions. They are very small and light-weight, and can be made relatively impervious to shock and other severe environmental conditions.

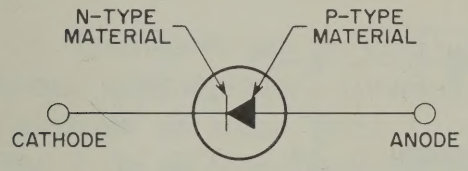


Fig. 3 — Schematic symbol for a silicon rectifier.

Fig. 4 shows the voltage-current characteristic for a silicon rectifier under both negative-bias and positive-bias conditions. When forward bias is applied (anode positive with respect to cathode), the rectifier behaves very much as a low resistance.

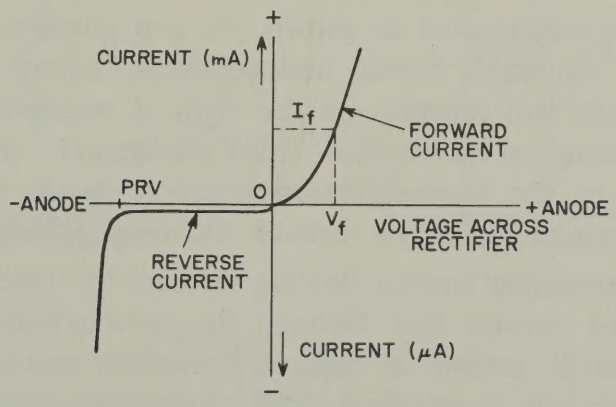


Fig. 4 — Voltage-current characteristics for a silicon rectifier.

The forward voltage drop V_f (usually about 0.6 volt) is the potential required to "break down" the p-n energy barrier. This voltage drop remains substantially constant as long as the average current in the circuit is within the rated value for the rectifier. However, if the voltage applied to the device is increased (either

deliberately or as a result of a voltage surge) to the point where the rated current is appreciably exceeded, the forward voltage drop becomes excessive and the rectifier may be permanently damaged.

Under normal reverse-bias conditions, the rectifier limits current flow to a few microamperes. If the reverse bias exceeds the peak reverse voltage (PRV) shown in Fig. 4, however, the reverse current increases very rapidly. Any increase in bias beyond this maximum rating may damage the rectifier. More than one diode can be connected in series in a bridge or full-wave circuit to obtain the PRV values required for high-voltage power-supply applications.

TRANSISTORS

Basically, a transistor can be considered as two diodes (p-n junctions) connected back-to-back, as shown in Fig. 5.

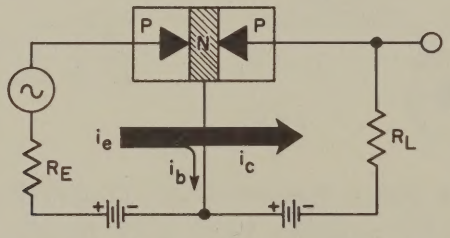


Fig. 5 — P-N-P transistor structure biased for power gain.

With a battery connected as shown, the p-n junction on the left is positively (forward) biased and conducts current easily (low resistance); the p-n junction on the right is negatively (reverse) biased and impedes current flow (high resistance). Almost all of the current in the forward-biased junction passes through the thin center region and flows through the reverse-biased junction. The small remaining current flowing through the base determines the degree of current flow through the reverse-biased junction. Because a small amount of current controls a much larger current, a power gain is achieved. This power gain makes the transistor useful as an amplifier and a signal-control (switch) device. (It should be noted that the transistor is a current-amplifying device, rather than a voltage-amplifying device like the vacuum tube.)

The schematic symbol for a transistor is shown in Fig. 6. The three electrodes of the device are called the emitter, the base, and the collector. In normal operation the emitter-to-base

junction is biased in the forward direction and the collector-to-base junction in the reverse direction. The arrow on the emitter lead identifies the transistor as a p-n-p or n-p-n type, and indicates the direction of conventional current flow in a circuit (electron flow is opposite to the direction of the arrow). This arrow always points toward the n-type material (as the arrow in a compass always points to the north, n), and is always in the direction of emitter current (conventional) flow.

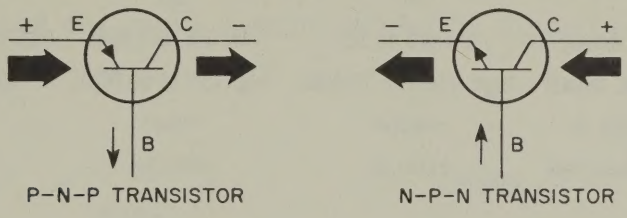


Fig. 6 — Schematic symbols for p-n-p and n-p-n transistors.

Transistors can be used in three possible circuit configurations: common-base, common-emitter, and common-collector. Diagrams of these three circuit configurations are shown in Fig. 7. In all three configurations the emitter current is the sum of the base and collector currents. Table I lists the properties of the three configurations.

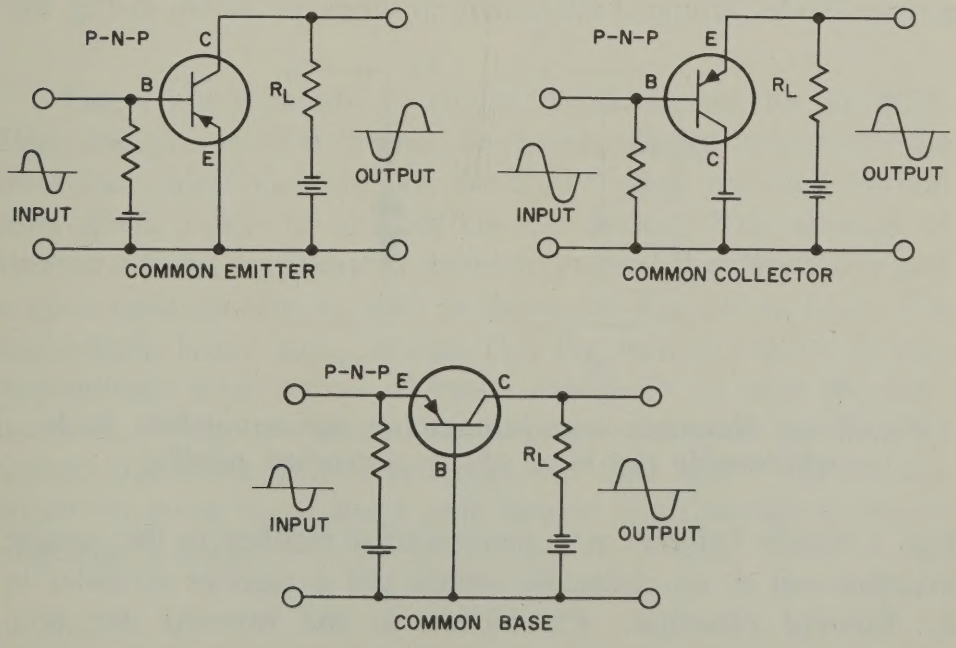


Fig. 7 — Common-emitter, common-collector, and common-base transistor circuit configurations.

Table I
Important Properties of the Three Transistor Circuit Configurations.

	Common-Base	Common-Emitter	Common-Collector
Voltage Gain	200 or more	200 or more	slightly less than 1
Current Gain	Slightly less than 1	approx. 50	approx. 50
Power Gain (Voltage Gain x Current Gain)	200 or more (Approx. same as voltage gain)	as high as 10,000	approx. 50 (same as current gain)
Phase Reversal	no	yes	no
Input Impedance (ohms)	low (10 to 50)	low (20 to 5,000)	high (5,000 to 100,000)
Output Impedance (ohms)	high (2000 to 10,000)	high (50 to 50,000)	low (5 to 5,000)
Input Signal Applied to	emitter	base	base
Output Signal Taken from	collector	collector	emitter

The circuits shown in this Manual use both germanium (p-n-p) and silicon (n-p-n) transistors; the forward voltage drop (voltage across the p-n junction when the transistor is conducting) is 0.4 volt in the germanium transistors and 0.6 volt in the silicon transistors.

SILICON CONTROLLED RECTIFIERS

If four semiconductor materials, two p-type and two n-type, are arranged as shown in Fig. 8a, the device can be considered as three diodes arranged alternately in series, as shown in Fig. 8b.

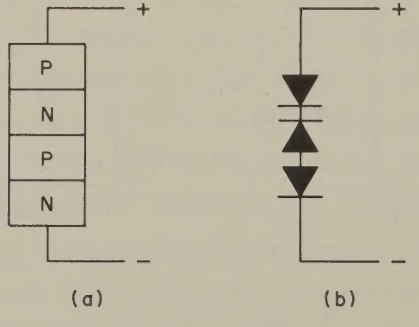


Fig. 8 — Materials arrangement (a) and equivalent diode relationship (b) in a silicon controlled rectifier.

Such a device behaves as a conventional rectifier in the reverse direction and as an electronic switch and a rectifier in series in the forward direction. Conduction in the forward direction, therefore, can be controlled or "gated' by operation of the switch. Such devices are known as silicon controlled rectifiers or thyristors.*

The schematic symbol for the silicon controlled rectifier (SCR) is shown in Fig. 9a; the gate lead is connected as shown in Fig 9b. In brief, the operation of this device is as follows: When a current source is applied to the gate-cathode circuit, the ensuing gate current (i_g), which flows easily through the bottom p-n junction to the cathode, causes an increase in the leakage current through the n-p junction (middle junction); in turn, this increased current flow (through transistor action) allows more current to flow through the top p-n junction. The effect is cumulative and the rapid current buildup is limited only by the external load.

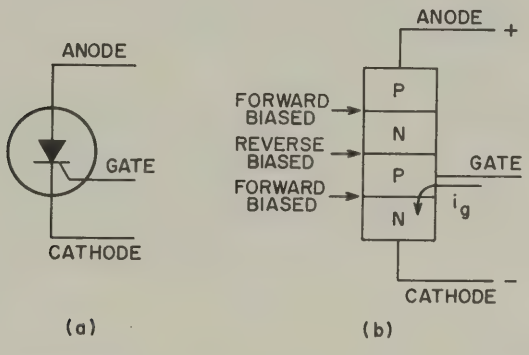


Fig. 9 — Schematic symbol (a) and lead connections (b) for a silicon controlled rectifier (SCR).

Fig. 10 is a family of typical characteristics for an SCR. When the gate current is zero, the anode voltage must reach the breakover value V_{BOO} before the SCR "turns on" and current flows from anode to cathode in the device. The amount of forward current necessary to maintain current flow when the gate is open (gate current is zero) is shown on Fig. 10 as I_{HOO}. For increasingly larger gate currents (I_G) the turn-on occurs at correspondingly lower values of anode voltage (V_{BO}) until the characteristic closely resembles that of a conventional rectifier. In normal operation, SCR's are operated well below the voltage breakover point V_{BOO}, and a gate current large enough to ensure triggering is used.

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* "Thyristor" is the generic term for semiconductor devices that have control characteristics similar to those of thyratron tubes. The silicon controlled rectifier is, more specifically, a reverse-blocking triode type of thyristor.

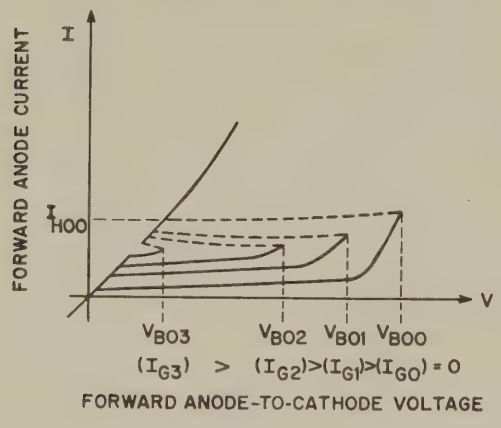


Fig. 10 — Typical voltage-current characteristics for an SCR.

In the reverse direction the SCR behaves exactly as a rectifier and precautions with regard to power ratings and peak-reverse-voltage ratings should be taken.

Fig. 11 shows an SCR circuit in its simplest form, together with typical waveforms for the applied voltages and the load energy. No current flows through the load until the SCR is

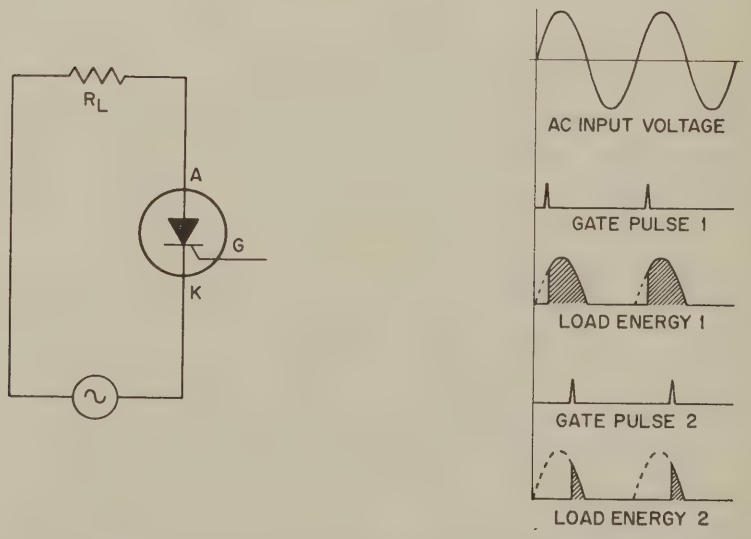


Fig. 11 — Simple SCR circuit and corresponding waveforms.

triggered; it can only be triggered and remain in conduction during the positive half-cycle of the ac input. The point at which the SCR is triggered, and therefore the amount of energy delivered to the load, is controlled by the instant during the positive half-cycle at which the gate pulse appears. If the gate pulse triggers the SCR in the early portion of the positive half-cycle, energy in the load is greater than if the triggering takes place in the later

portion of the positive half-cycle. The waveshapes shown in Fig. 11 illustrate the control feature of the SCR. After the SCR is triggered, the gate loses control and the device continues to conduct as long as the anode voltage is sufficiently positive with respect to the cathode to maintain the holding current, I_{HOO}. In ac circuits such as that shown in Fig. 11, the SCR is cut off during each negative half-cycle and the gate regains control on each positive half-cycle. In dc applications, turn-off is not "automatic" and special turn-off circuits are required.

An important feature of the SCR is its low power loss compared with the amount of power it controls. For example, the SCR used in the kit associated with this Manual controls as much as 350 watts of power but has a maximum power loss of less than two watts (3.2 max amperes x 0.6 volt), an insignificant amount compared to the power loss in a rheostat required to control the same amount of power.

A more detailed explanation of how typical SCR control circuits operate is given in the individual circuit descriptions later in this Manual.

General Description and Application Considerations

AS mentioned previously, the circuits in this Manual are designed to use the components contained in the **RCA Silicon Controlled Rectifier Experimenter's Kit KD2105.** This kit includes eight components: one silicon controlled rectifier or SCR (KD2100) mounted on a heat sink, five silicon rectifiers (four KD2103 and one KD2104), one silicon transistor (KD2102), and one germanium transistor (KD2101). These components have been selected to provide the user with maximum flexibility in the variety and number of circuits which he can build at a minimum cost.

Fourteen of the circuits described in the Manual (the Single-Kit Circuits) use one Kit KD2105; the remaining ten (the Twin-Kit Circuits) are more advanced and require two KD2105 Kits each. The outstanding feature of the Twin-Kit Circuits is their ability to handle up to one kilowatt of power in all loads but incandescent-lamp loads. (Because of initial surge current, only 660 watts of power can be accommodated in incandescent-lamp loads.) Except for the Twin-Kit Battery Charger and the Kit Tester, all circuits can be constructed on one of three standard or basic chassis. Only commercially available small tools are required for preparation of the chassis and mounting of the components required for each circuit in the Manual.

DESCRIPTION OF KIT COMPONENTS

The SCR and its heat-sink mounting are shown in Fig. 12. The terminal diagram for the SCR is shown in Fig. 13. Because the case is electrically insulated from the angle bracket by means of a mica washer, no special precautions are necessary when the KD2100 is mounted to the chassis. The soldering lug is connected to the case which, in turn, is connected to the anode of the SCR. This lug also is electrically insulated from the angle bracket by means of a Teflon bushing.

The KD2103 and KD2104 silicon rectifiers are identical in shape and size; their photograph and schematic symbol are shown in Fig. 14. The KD2104 has a lower peak-inverse-voltage rating than the KD2103 and is used as a diode in the circuits shown in this Manual. The KD2103 silicon rectifiers are used almost exclusively in a full-wave bridge configuration, although in

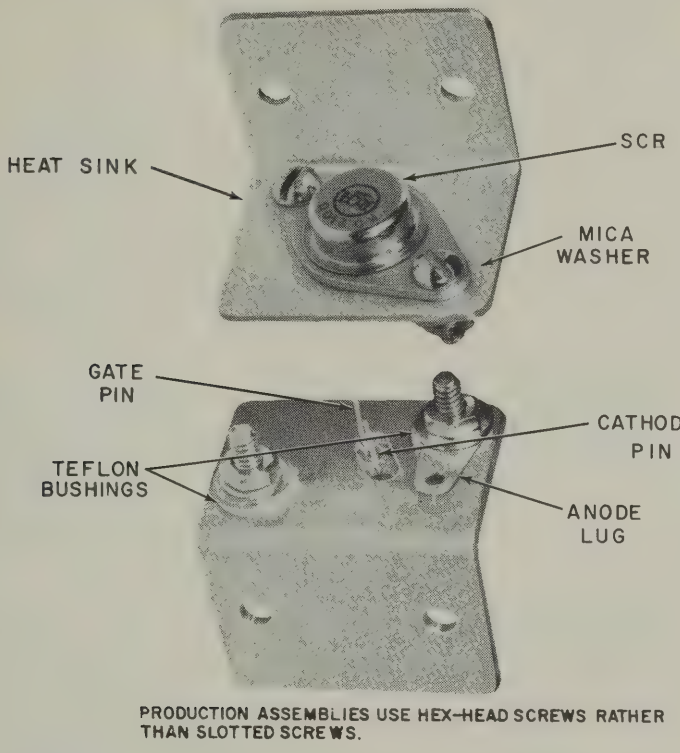


Fig. 12 — Silicon controlled rectifier KD2100 mounted on a heat sink (as supplied in Kit KD2105).

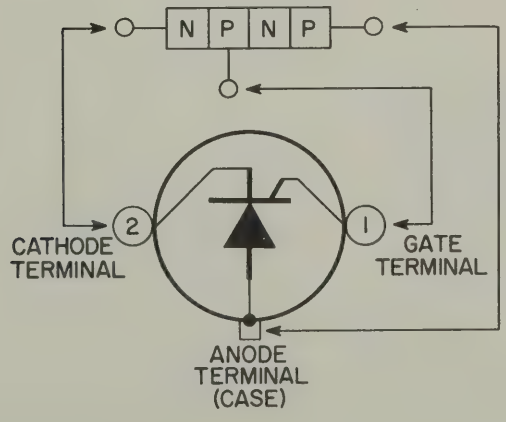


Fig. 13 — Terminal diagram for SCR KD2100.

one circuit increased output current is achieved by use of two rectifiers in parallel in each leg of a full-wave center-tapped configuration. Mounting details and schematic representations for these rectifier configurations are shown later in this section.

Photographs, schematic symbols, and terminal connections for the KD2102 and KD2101 transistors are shown in Figs. 15 and 16, respectively. The KD2102 is an n-p-n silicon transistor; the KD2101 is a p-n-p germanium transistor. In most of the

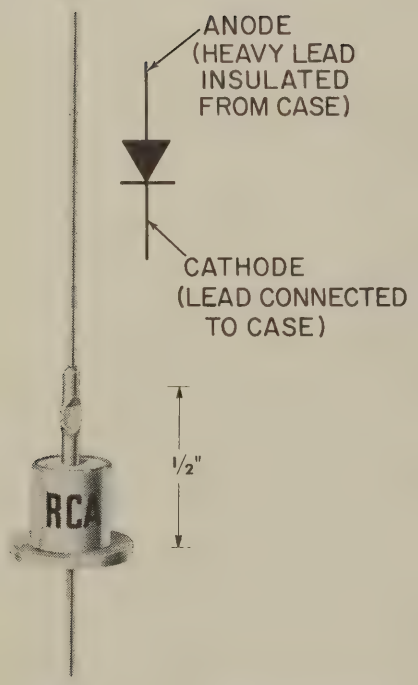


Fig. 14 — Photograph and schematic symbol for silicon rectifiers KD2103 and KD2104.

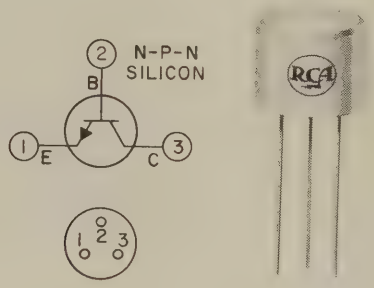


Fig. 15 — Schematic symbol, terminal connections, and photograph of KD2102 n-p-n silicon transistor.

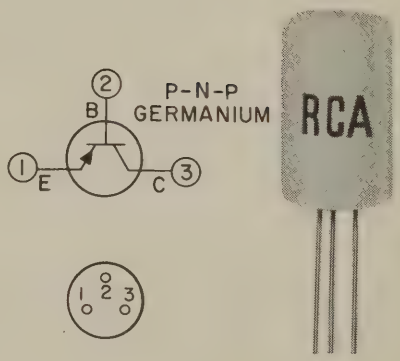


Fig. 16 — Schematic symbol, terminal connections, and photograph of KD2101 p-n-p germanium transistor.

circuits in this Manual, these transistors are used in a two-transistor regenerative switch which is also described later in this section.

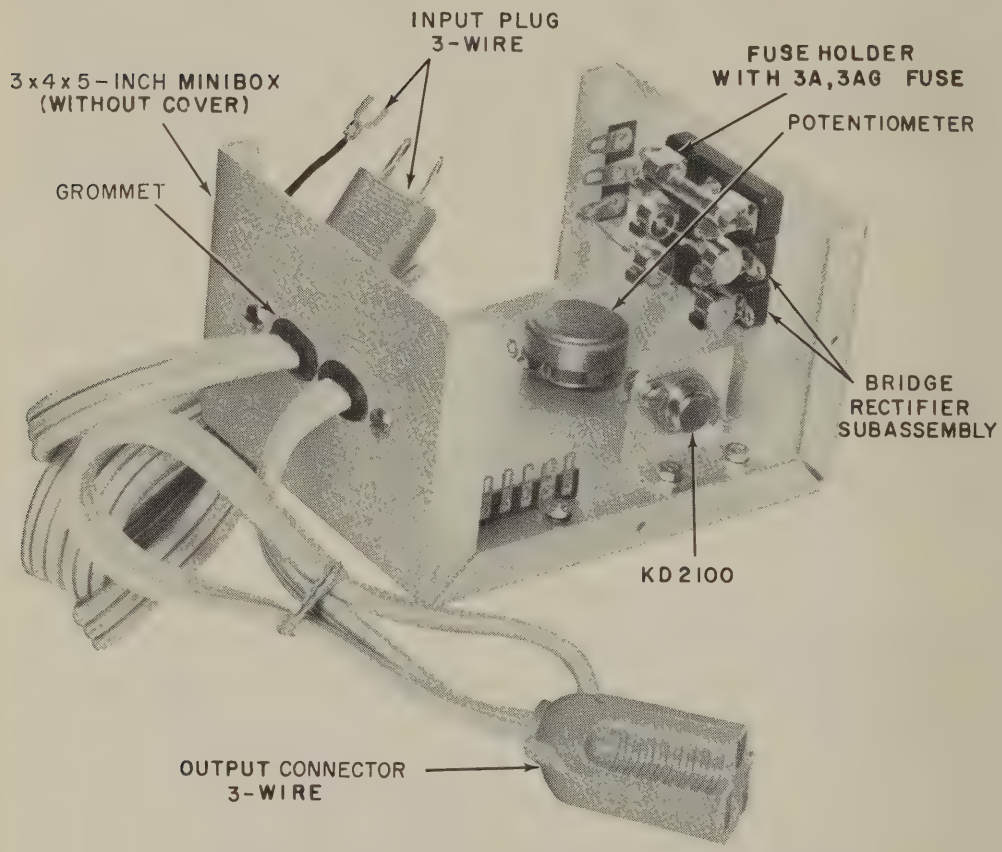
BASIC CHASSIS

The underlying concept in the design of the control circuits in this Manual is to provide maximum flexibility in construction. Consequently, three basic chassis were designed on which the components and subassemblies common to the various circuits can be mounted. In addition, two special chassis were designed, one for the Kit Tester and one for the Twin-Kit Battery Charger. When the basic chassis have been constructed, experimenters can build any individual circuit simply by adding passive components such as resistors, potentiometers, and capacitors, or can change from one circuit to another simply by changing the passive components. Three of the circuits in the Manual also use the **RCA Add-On Light Sensor Kit KD2106,** which consists of a single photocell; three others use the **RCA Add-On Heat Sensor Kit KD2110,** which contains three thermistors. These kits are described later in this section.

The basic chassis A, shown in Figs. 17 and 18, is a 3 x 4 x 5-inch aluminum two-piece Minibox. This chassis is used for eleven of the twenty-four circuits in the Manual, with only minor changes required in the basic design. A potentiometer such as that shown in Fig. 17 is used in all but one of the circuits, but the resistance value is changed for individual circuits. The single-pole, single-throw switch shown in Fig. 18 is also replaced by a double-pole, double-throw switch for two of the eleven circuits. In addition, the two transistors are used as a two-stage amplifier rather than as a regenerative switch in one circuit.

The basic chassis B, shown in Fig 19, uses a 6 x 5 x 4-inch aluminum two-piece Minibox. A transformer is also used as a part of this basic chassis, but is not shown in the photograph because it would obscure the other components. The 3-wire line cord connected directly to the transformer is also not shown. The rectifier subassembly is mounted half on either side of the transformer, as shown, for use as a bridge rectifier.

Basic chassis C, shown in Fig. 20, is used for all Twin-Kit Circuits except the Battery Charger. It consists of a 3 x 4 x 5-inch aluminum two-piece Minibox identical to the one used in basic chassis A but drilled differently to accommodate components required in the Twin-Kit Circuits.



Chassis, 3x4x5-inch with cover; Minibox or equivalent
Extension cord, 3 wire, 6 foot; cut convenient length (approximately 6 inches) from female end and use female end as output connector
Fuse, 3 ampere, type 3 AG
Fuse holders, 3 AG Littelfuse or equivalent; 3 required
Grommets, 3/8-inch O.D., rubber; 2 required
Knob, for 1/4-inch-diameter shaft
Switch, SPST, toggle, 3 ampere, 125 volts
Terminal strips, miniature, H.H. Smith No.1070 or equivalent; 2 required
Terminal Strips, Cinch-Jones No.52A or equivalent; 3 required
Hardware: 2-56 and 6-32 screws, nuts, and lockwashers

Fig. 17 — View of basic chassis A showing SCR and rectifier subassembly.

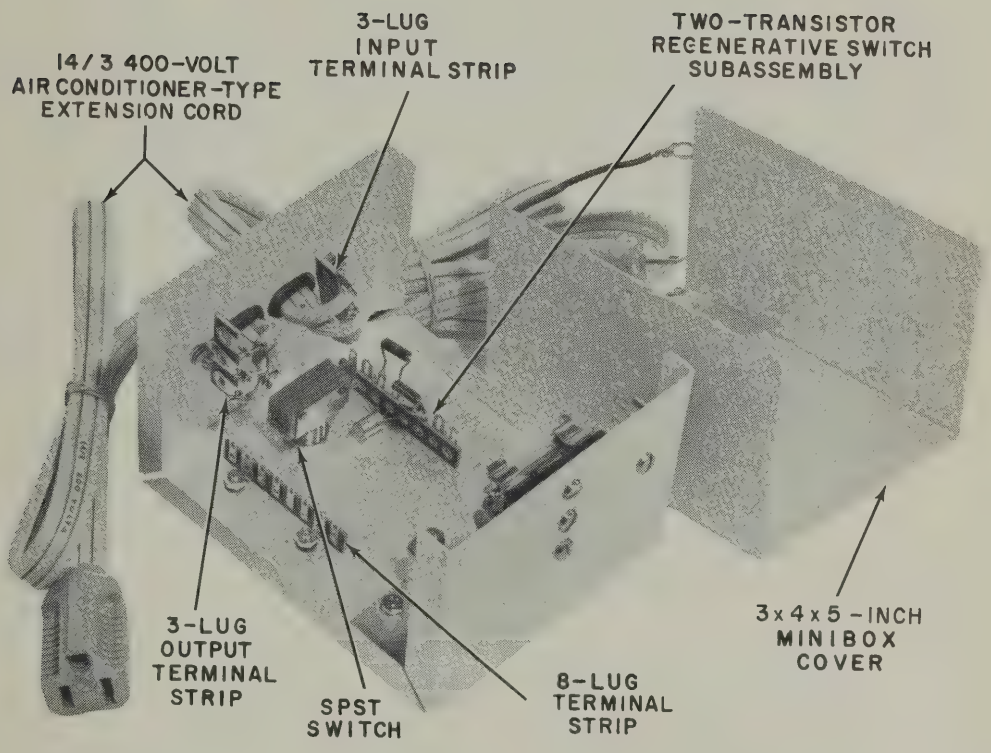
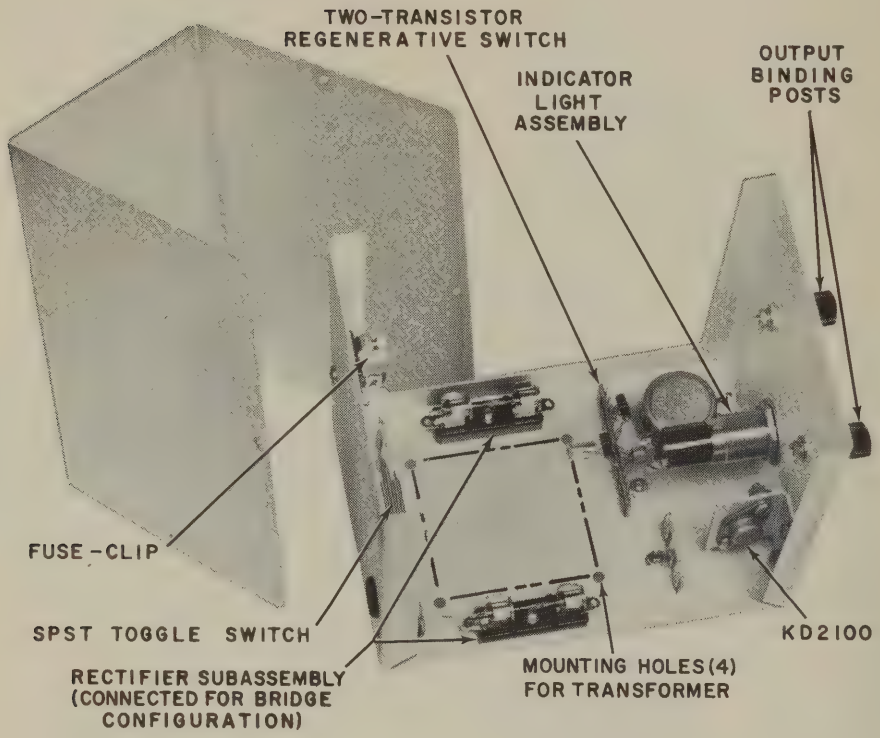
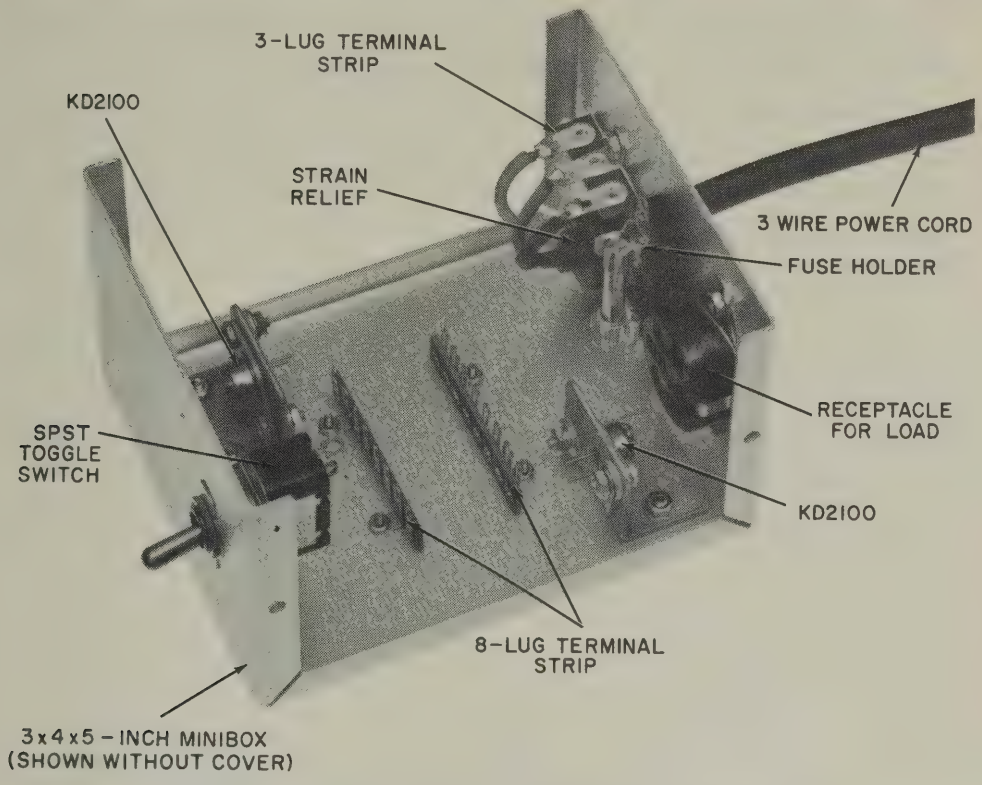


Fig. 18 — View of basic chassis A showing transistor subassembly, terminal strips, and switch.



Chassis, 4x5x6-inch with cover; Minibox or equivalent
Binding Posts, Eby or equivalent; 2 required
Cord set, appliance, 3 wire, 8 feet, Belden No.17408SJ
or equivalent
Fuse, 1 ampere, type 3AG
Fuse holders, 3AG Littelfuse or equivalent; 3 required
Knob, for 1/4-inch-diameter shaft
Light assembly, pilot, Dialco No.812210 or equivalent
Switch, SPST, toggle, 3 ampere, 125 volts
Terminal strips, Cinch-Jones No.52A
or equivalent; 3 required
Terminal strip, miniature, H.H. Smith No.1070
or equivalent
Transformer, power, Stancor RT-202 or equivalent
Hardware: 2-56, 6-32, 8-42 screws, nuts, and lockwashers

Fig. 19 — View of basic chassis B (transformer not shown).



Chassis, 3x4x5-inch with cover, Minibox or equivalent
Fuse, 10 amperes, type 3AG
Fuse holder, 3AG Littelfuse or equivalent
Power Cord, 3 wire, No.16 AWG
Receptacle, Amphenol No.160-2 or equivalent
Strain relief, Heyco 7P or equivalent
Switch, SPST, toggle, 15 amperes, 125 volts
Terminal Strip, Cinch-Jones No.52A
or equivalent
Terminal Strips, miniature, H.H. Smith No.1070
or equivalent; 2 required
Hardware: 6-32 and 2-56 screws, nuts and lockwashers

Fig. 20 — View of basic chassis C.

CHASSIS LAYOUTS

Drilling details for the basic chassis A, B, and C are shown in the isometric drawings of Figs. 21, 22, and 23, respectively. The tools needed to prepare the chassis for mounting of the circuit components are as follows:

a ¼-inch drill (electric or mechanical egg-beater type);
a scale (6- or 12-inch ruler);
a center punch (or a large sharp nail);
drills: #31, #42, #25, 3/16-inch, 1/4-inch;
a reamer large enough to ream to a diameter of at least ¾ inch;
a small hammer.

Holes that are greater than ¼-inch in diameter can be reamed to the required diameters. In general, all holes larger than #25 drill size should first be "located" (drilled) with a small drill (#31 or smaller) before the larger drill is used. A vise, although not absolutely necessary, is very helpful and improves safety.

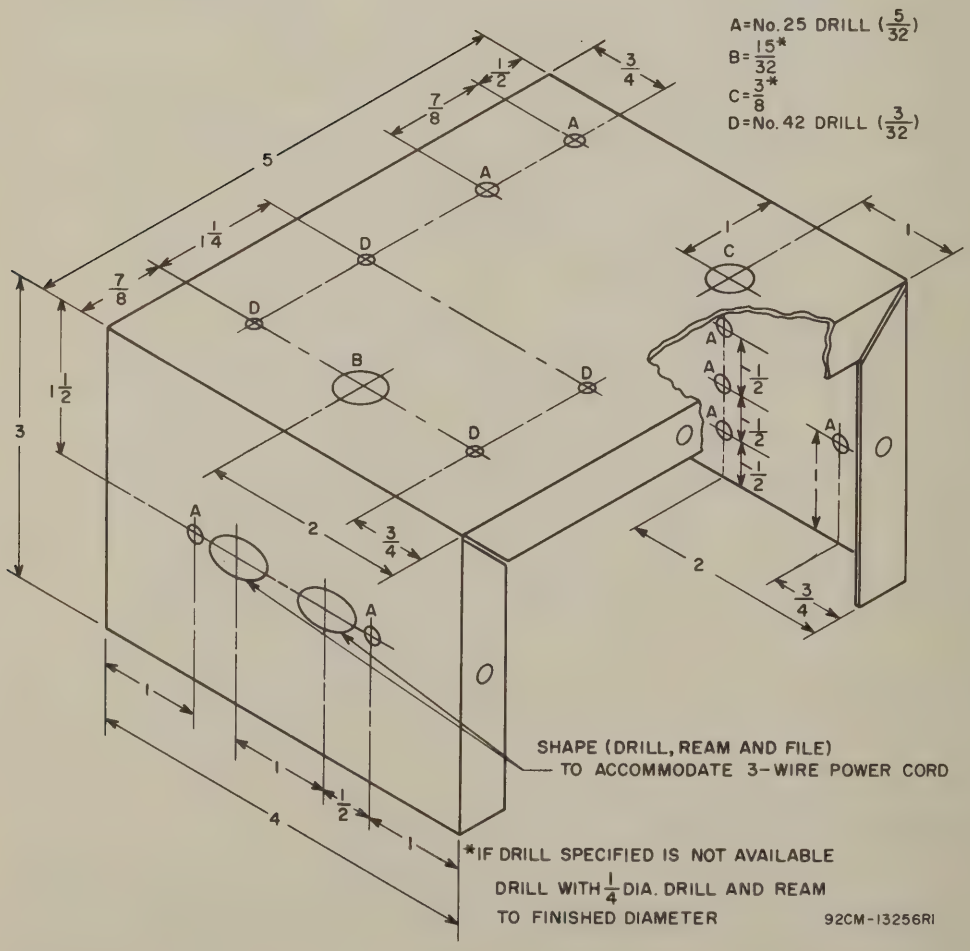

A=No. 25 DRILL (5/32)
B=15/32*
C=3/8*
D=No. 42 DRILL (3/32)
SHAPE (DRILL, REAM AND FILE) TO ACCOMMODATE 3-WIRE POWER CORD
*IF DRILL SPECIFIED IS NOT AVAILABLE DRILL WITH 1/4 DIA. DRILL AND REAM TO FINISHED DIAMETER
92CM-13256RI

Fig. 21 — Drilling details for basic chassis A.

SUBASSEMBLIES

The **bridge rectifier subsassembly** is shown in Fig. 24. The Littelfuse fuse holders in which the KD2103 silicon rectifiers are mounted are modified as shown in Fig. 25. Because the cathode lead of each KD2103 is connected to the case, the clip and lug of each section of the holder serve as the cathode connection for each KD2103. The clip and lug on each holder closest to the terminal strip are used to connect the line voltage between the anode and cathode of each pair of KD2103 rectifiers.

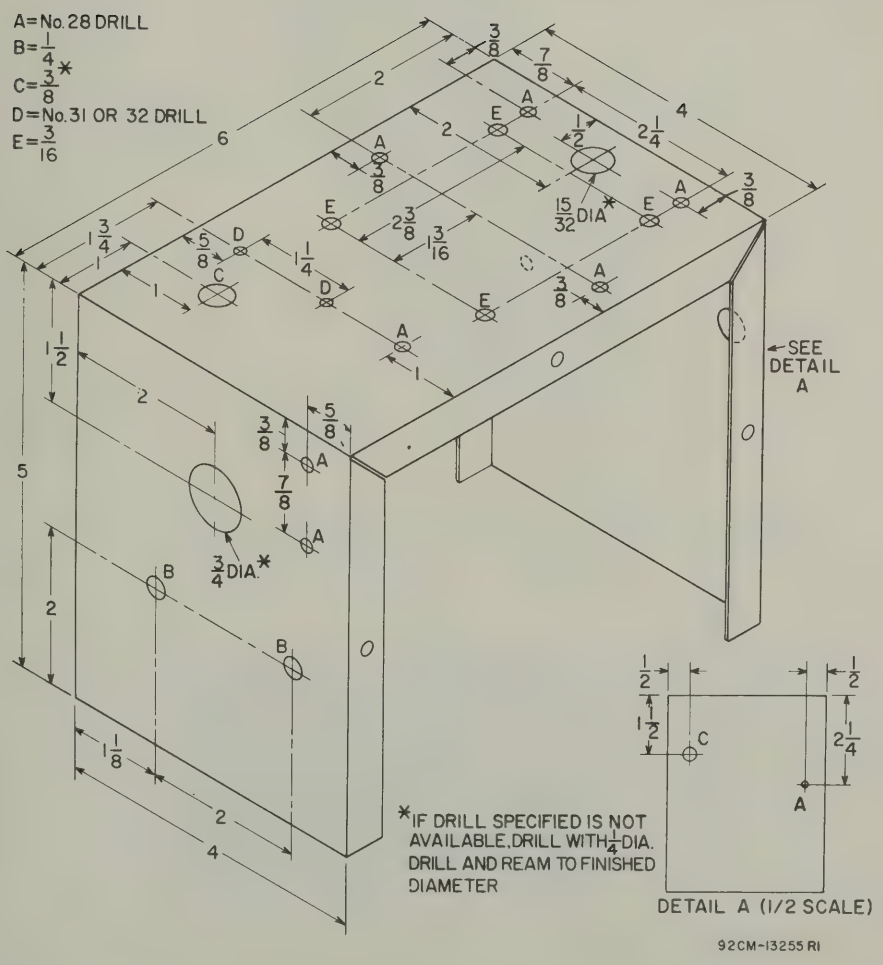

A=No. 28 DRILL
B=1/4*
C=3/8
D=No. 31 OR 32 DRILL
E=3/16
SEE DETAIL A
*IF DRILL SPECIFIED IS NOT AVAILABLE, DRILL WITH 1/4 DIA. DRILL AND REAM TO FINISHED DIAMETER
DETAIL A (1/2 SCALE)
92CM-13255 RI

Fig. 22 — Drilling details for basic chassis B.

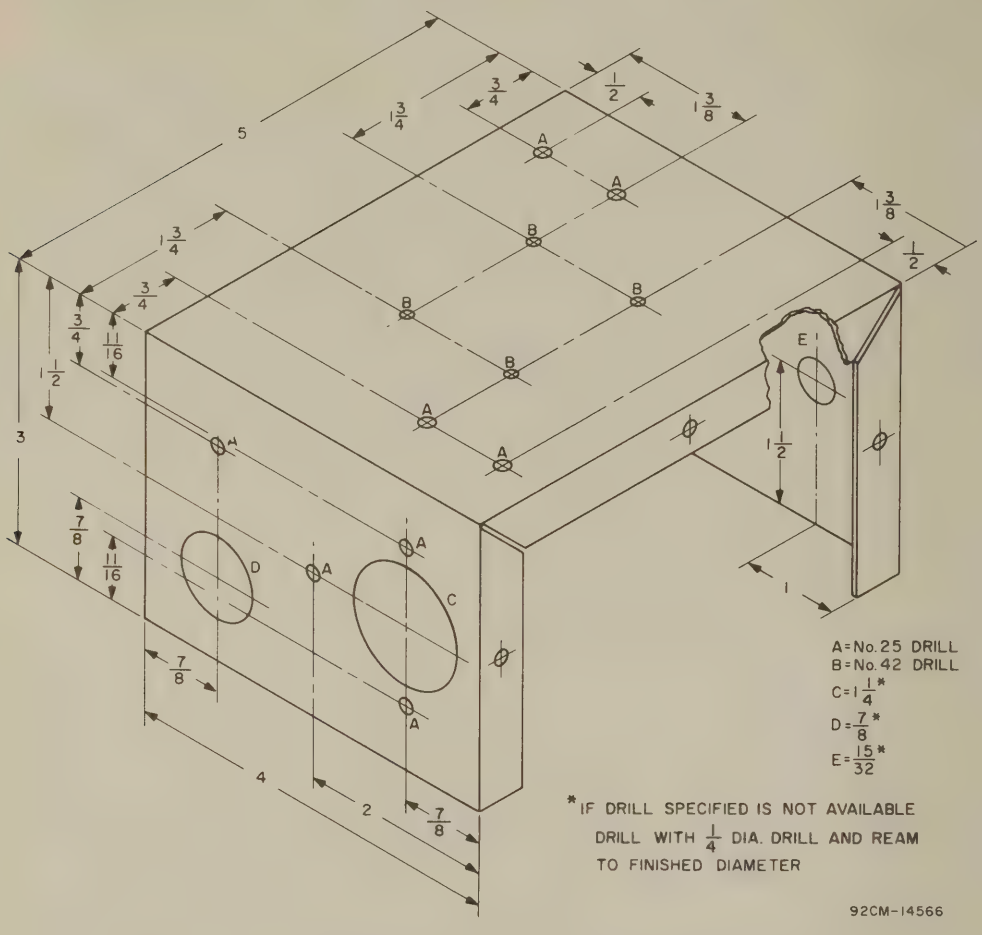


Fig. 23 — Drilling details for basic chassis C.

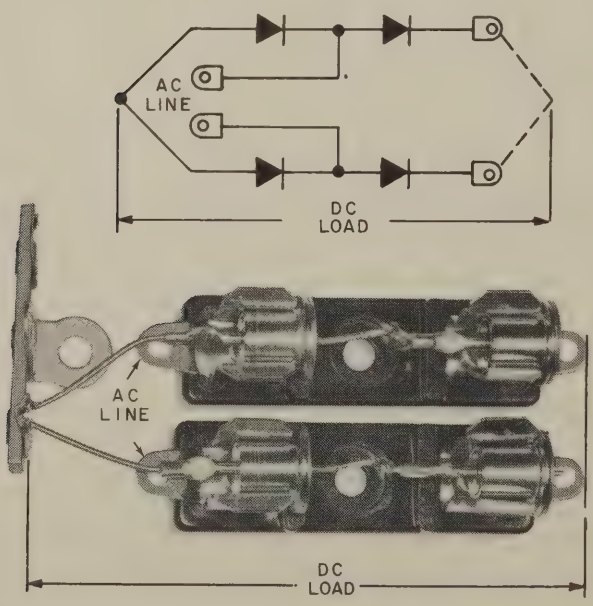


Fig. 24 — Photograph and schematic representation of bridge rectifier subassembly.

For a full-wave center-tapped configuration, the KD2103 silicon rectifiers are arranged with their anodes back-to-back (as shown in Circuit No. 9 in the **Circuits** section). The two anode terminals in each fuse holder are soldered together, and the clips on each holder are also soldered together.

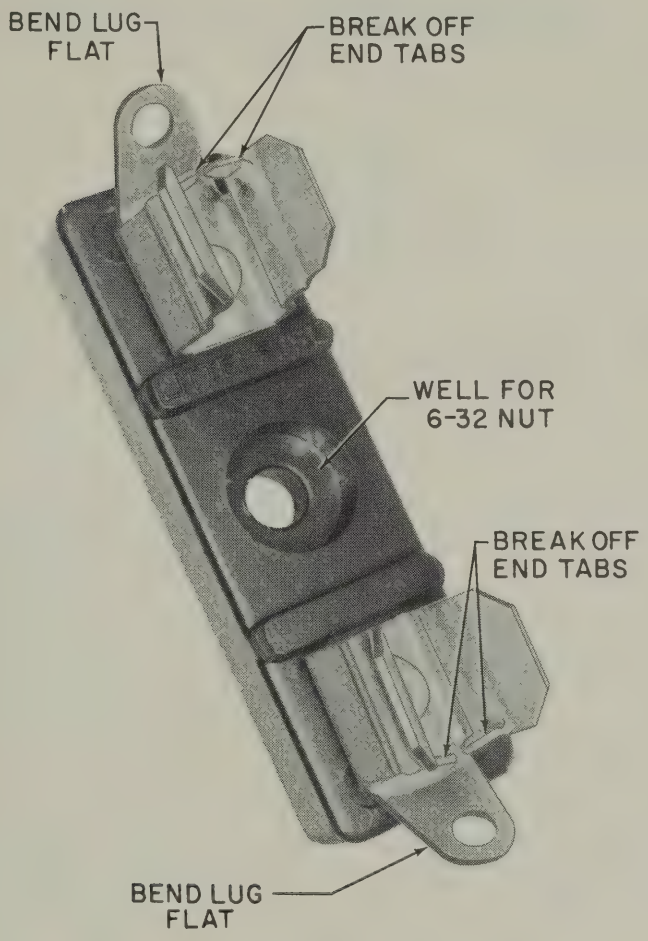


Fig. 25 — Photograph showing modifications made to Littelfuse fuse holders.

The **two-transistor regenerative switch** shown in Figs. 26 and 27 consists of the two transistors KD2101 and KD2102 and two resistors, R_2 (150 ohms) and R_3 (470 ohms). (In two of the circuits, the 150-ohm fixed resistor R_2 is replaced with a 250-ohm variable resistor which is used as a sensitivity control.) The two resistors stabilize the "switch" by preventing leakage currents in the emitter-base circuits of the transistors from inadvertently triggering the switch if the ambient temperature increases. The use of one germanium and one silicon transistor also increases temperature stability.

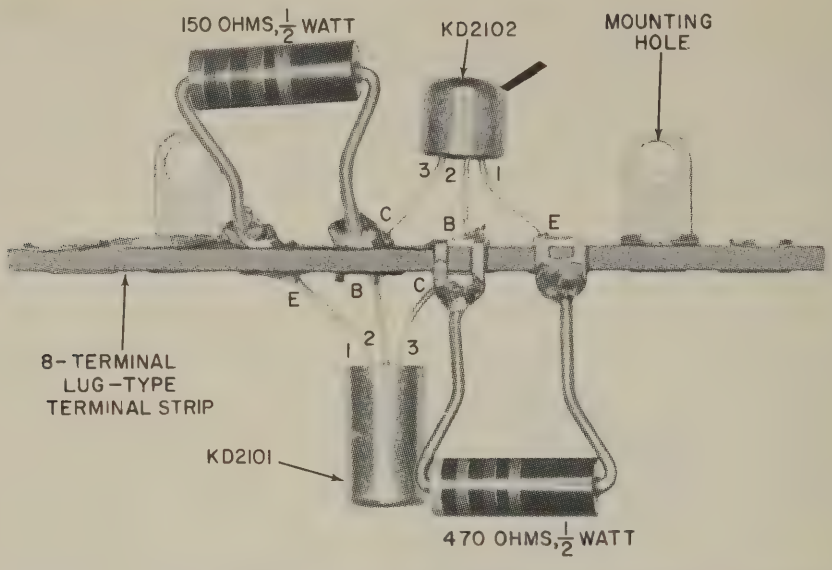


Fig. 26 — Photograph of two-transistor regenerative-switch subassembly.

The basic theory of operation of this transistor "switch" is that a small change in the base current of either transistor upsets the stability of the circuit. The output from the "triggered" transistor then feeds the input of the other transistor, which in turn feeds its output to the input of the first transistor. This regenerative behavior creates a high-conductivity path that can be used for such purposes as discharging a capacitor or making or breaking a gate-current circuit to an SCR.

The operation of the regenerative switch is illustrated in Fig. 27. In the arrangement shown in Fig. 27a, resistor R_1 provides

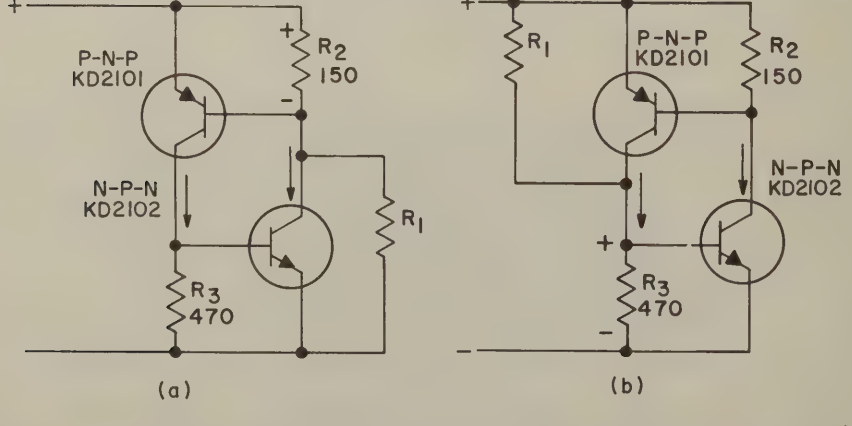


Fig. 27 — Schematic diagrams for two-transistor regenerative-switch subassembly.

a conduction path for resistor R_2. A positive-going signal on the emitter of KD2101, the p-n-p transistor, produces a signal across R_2 which causes KD2101 to conduct. The output from KD2101 feeds current into the base of KD2102, the n-p-n transistor, and KD2102 conducts and draws more current out of the base of KD2101. This action increases the collector current of KD2101 and, in turn, the base current of KD2102. In a very short time the transistors reach full conduction (become "saturated"), and the voltage drop across the switch is reduced to one volt (0.4 volt across KD2101 and 0.6 volt across KD2102).

In the arrangement shown in Fig. 27b, R_1 provides a conduction path for R_3, and the signal developed across R_3 triggers KD2102 into conduction to effect the saturation or "closing" of the switch. The ratio between R_1 and either R_2 or R_3 determines the "triggering"-voltage level for the switch. Because R_1 varies for different circuits, it is not considered part of the switch assembly as mounted on the basic chassis.

The following recommendations are given for construction of the regenerative switch shown in Fig. 26:

1. The resistor leads should be bent and the leads of all four components should be inserted in the proper lugs (in accordance with the pattern shown in Fig. 26) before any soldering or cutting of the leads is attempted.

2. After all connections are checked, they should be soldered by use of a small, hot, well-tinned soldering iron and a good-quality rosin-cored solder. The soldering-iron tip and the solder should be applied to the lug simultaneously and held there only until the melted solder wets the lug and the leads. The soldering iron should then be removed quickly, and the joint should be blown on so that it cools quickly. As an added precaution, especially during soldering of the leads of the KD2101 germanium transistor, an alligator clip can be clipped to the lead between the lug and the transistor case. This temporary "heat sink" absorbs heat that could otherwise damage the transistor.

3. After all four lugs have been soldered, the excess portion of each lead can be cut with a pair of diagonal cutters.

The procedure described above eliminates excessive mechanical stress on the transistors, and also minimizes the amount of heat to which the transistors are subjected because heat is applied only once to each lug.

CONSTRUCTION TIPS AND DETAILS

Before actual construction is started, a component layout should be made. This procedure will help insure correct wiring during construction and act as a check of the availability of the proper components.

When solder connections are made to the SCR and the silicon diodes, the same precautions described above for transistors should be taken to avoid excessive heat and mechanical stress. For all other components, the following rules of good soldering practice apply:

1. Before solder is applied, a good mechanical connection should be made by twisting the wire around the terminal post or lug. Soldering should be considered as a means for making a good electrical connection, not a mechanical one. A pencil-type soldering iron rated below 100 watts is best for soldering the circuits in this Manual.

2. For good heat conduction between the soldering iron and the mechanical joint, a small amount of solder should be applied to the tinned portion of the soldering-iron tip, and this surface should be applied to the joint. The solder (rosin-cored) is then applied to the joint, but is not brought into contact with the iron; when the solder melts, the joint is properly soldered. This procedure avoids a "cold solder joint" that could cause trouble at some future time.

3. The stripped ends of heavy solid wire or flexible multistrand wire as used in line cords should be tinned (heated and "wetted" with solder) before the mechanical connection to the lug or terminal is made. This tinning procedure provides a quick, clean, hot solder joint. Tinning of heavy terminals such as those used on toggle switches is also a good practice. With ordinary hook-up wire, tinning is not necessary.

4. If a knife is used to strip the insulation from the end of a wire, the knife should be dull so that it will not nick the wire. If diagonal cutters are used, they should be squeezed only tightly enough to cut and pull the insulation.

In addition to the tools already mentioned, a pair of long-nosed pliers is also very useful for bending wires and leads and for wrapping leads around lugs or terminals.

TROUBLESHOOTING

An experimenter's success in troubleshooting the control

circuits in this Manual will be directly related to his familiarity with them and his knowledge of their operation. The test equipment available and the facility with which it is used are also very important factors.

Typical waveshapes at various key points are shown for the first circuit in the **Circuits** section at maximum, 90-degree, and minimum conduction angles. Although such waveshapes and an oscilloscope are not absolutely essential for troubleshooting, they can be valuable as an aid to understanding the operation of the various circuits. Waveshapes taken when the circuits (especially the power control type) are operating properly can be very useful for comparison purposes when trouble occurs.

Voltage and current readings obtained by use of an RCA volt-ohm-milliammeter (VOM) can also be very helpful in troubleshooting. The voltages indicated on the circuit schematics are typical readings obtained when the circuits were constructed. These readings were taken with an RCA WV38A VOM.

The following checkout procedure, although not absolutely foolproof, is recommended for use when a circuit is first turned on or when troubleshooting is attempted:

1. Before power is applied to the circuit for the first time, the wiring should be checked for agreement with the schematic and the *load* should be checked to ensure that it is *within the rated value* and is of the *proper type*.

2. If the circuit fails to operate, the load should be observed for any signs of energization, such as the flash of a lamp, the start of a motor, or the like.

3. When trouble occurs, the power-input cord should be removed from the power receptacle; the cover of the Minibox can then be removed so that the fuse can be checked.

4. If the fuse has blown, the wiring should be rechecked for short circuits; special attention should be given to electrolytic-capacitor and silicon-rectifier polarities. The load should also be checked: Is it ac/dc? If ac, is it used in the line side of the bridge rectifier? Is its cold resistance too low (as would be the case if the load were a photoflood lamp)?

5. If the fuse has not blown and the load shows no evidence of being energized, the wiring should be rechecked; an open circuit caused by faulty wire is the most probable cause of the trouble.

6. Voltage and resistance checks by use of a VOM are the next step in isolating the trouble area. If one of the active kit components is suspected, it can be tested for "go/no-go" operation through the use of the circuits described and illustrated later in this section or the Kit Tester described in the next section. (The test will only indicate whether the component will rectify or conduct; it will not indicate how well or with what gain the component operates in the circuit.) If all active components are found to be in working order, the passive components should be checked: capacitors for shorts and leakage, and wire-wound resistors and potentiometers for discontinuities. Passive components, especially new ones, that display no visible irregularities are usually trouble-free and therefore are least likely to be the cause of a circuit failure.

7. If the circuit is operating but the performance is not as expected, the trouble might be caused by the tolerances of various components adding in the same direction. When this situation is suspected, a change to the next higher or lower resistance or capacitance value or the mere substitution of another component of the same value may produce a significant change in circuit operation. As mentioned previously, success in this type of trouble-shooting depends to a large extent on the experimenter's familiarity with and understanding of the circuits involved.

SIMPLE TEST CIRCUITS FOR KIT COMPONENTS

Kit components may be tested with the simple, temporary circuits shown in this section or with the Kit Tester described in the next section. The advantage of the Kit Tester is its permanence; it enables the experimenter to test components at any time without having to set up a number of special circuits. The Kit Tester is constructed by the experimenter.

Fig. 28 shows a simple "go/no-go" test circuit for the silicon rectifier diodes KD2103. With the connections shown, the lamp operates at half-power. When the switch is closed, the lamp should brighten if the diode under test is good. If there is no change in brightness when the switch is closed, the lamp was burning at full power with the switch open; in this case, the diode is shorted. If the lamp is out with the switch open but lights when the switch is closed, the diode is open.

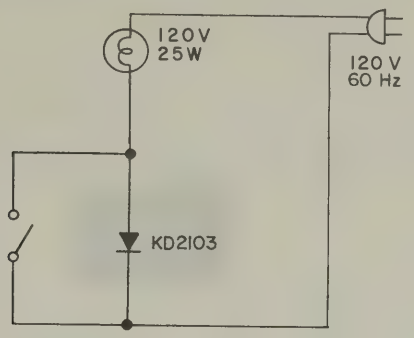


Fig. 28 — "Go/no-go" test circuit for silicon rectifier KD2103.

Fig. 29 shows a "go/no-go" tester for silicon rectifier KD2104. With the polarity of the battery as shown, the lamp should light; when the polarity of the battery is reversed, the lamp should not light. If the lamp lights regardless of the polarity of the battery, the diode is shorted; if the lamp does not light with either polarity, the diode is open.

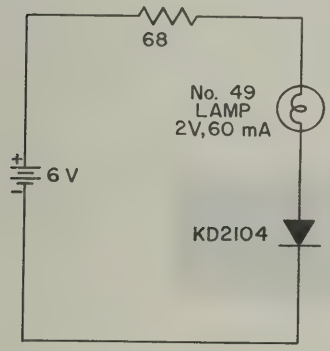


Fig. 29 — "Go/no-go" test circuit for silicon rectifier KD2104.

The test circuit shown in Fig. 30 can be used to check the two-transistor regenerative switch. When the 1000-ohm resistor is inserted in the circuit, the No. 49 lamp lights. If the transistor "switch" is operating properly, the lamp should remain lighted when the 1000-ohm resistor is removed.

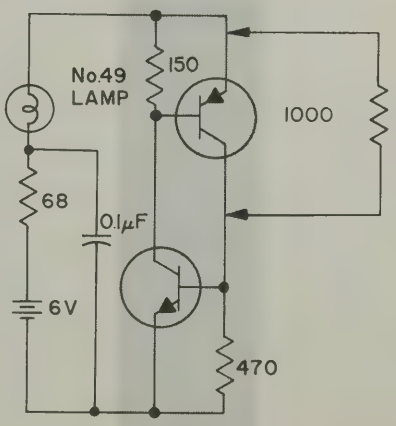


Fig. 30 — Simple test circuit for two-transistor regenerative switch.

Fig. 31 shows a "go/no-go" tester for the transistors KD2101 and KD2102. The connections shown are for the n-p-n transistor KD2102. When the base resistor is connected to the plus side of the battery, the No. 49 lamp should light if the KD2102 is

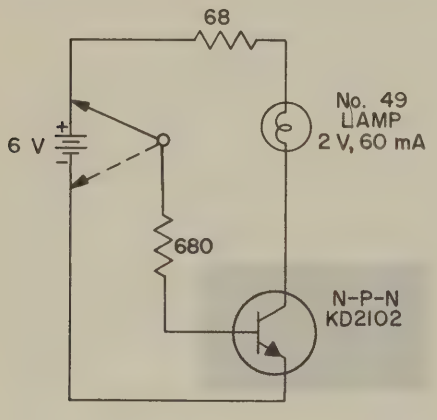


Fig. 31 — "Go/no-go" test circuit for transistors KD2102 and KD2101.

operative. When the base resistor is connected to the minus side of the battery, the lamp should go out. For the p-n-p transistor KD2101, the same results should be obtained with the battery polarities reversed.

The SCR KD2100 can be tested by means of the circuit shown in Fig. 32. When the switch is closed, a current of

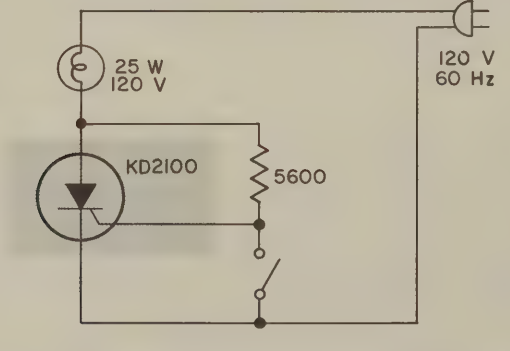


Fig. 32 — Simple test circuit for SCR KD2100.

approximately 20 milliamperes flows through the 25-watt lamp, the 5600-ohm resistor, and the switch; this value of current is not enough to light the lamp. When the switch is opened, the lamp should brighten to approximately half maximum brightness. Under these conditions, the SCR should be triggered into operation (shunting the 5600-ohm resistor) on each positive half-cycle of input by the current of 20 milliamperes flowing in the gate-cathode circuit. If the lamp lights to full brightness, the SCR is shorted. If the lamp does not brighten regardless of the position of the switch, then the SCR is "open".

KIT TESTER

The Kit Tester combines the simple test circuits in one permanent chassis. It can be used for "go/no-go" tests of all components in the **Silicon Controlled Rectifier Experimenter's Kit KD2105.**

CONSTRUCTION

Photographs of the Kit Tester are shown in Fig. 33. The Tester uses a specially drilled 3 x 4 x 5-inch Minibox. This special chassis and a list of components are shown in Fig. 34; the circuit diagram appears in Fig. 35.

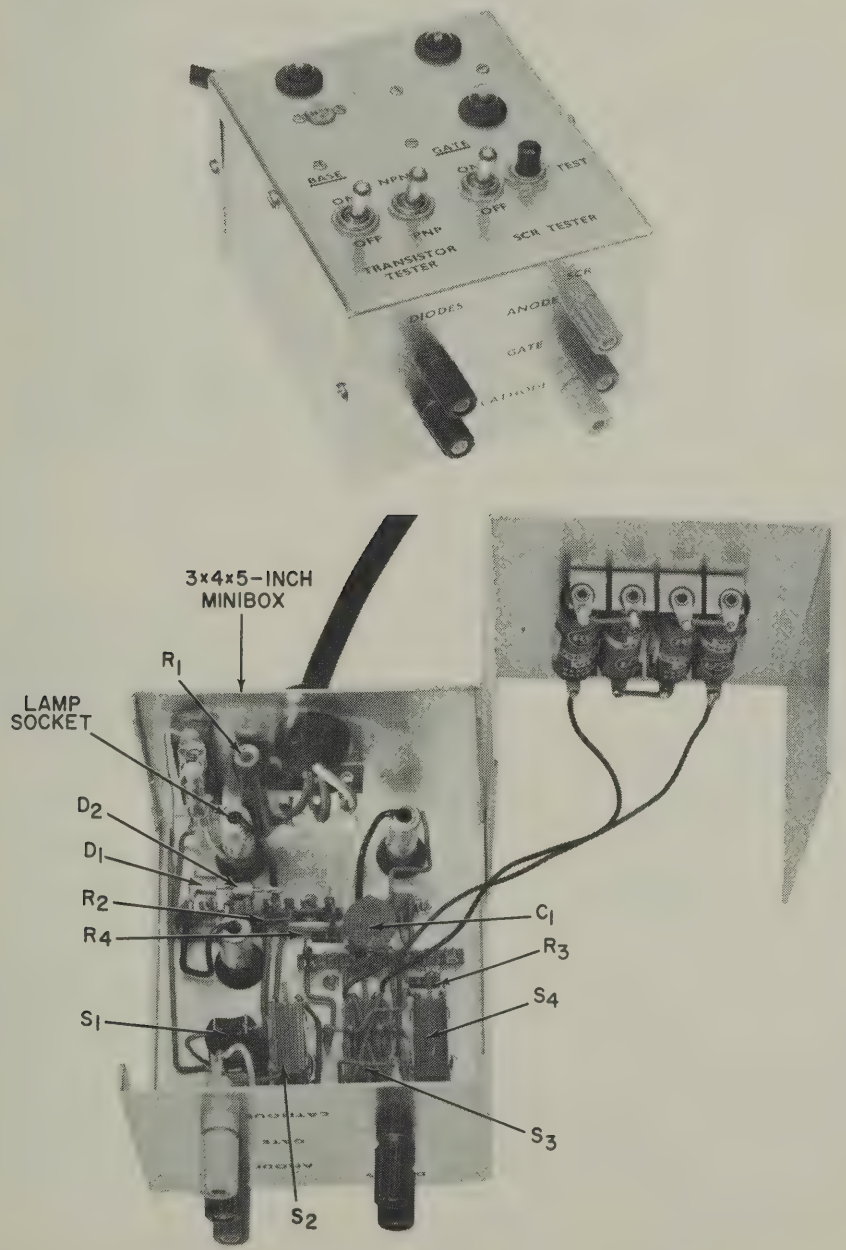
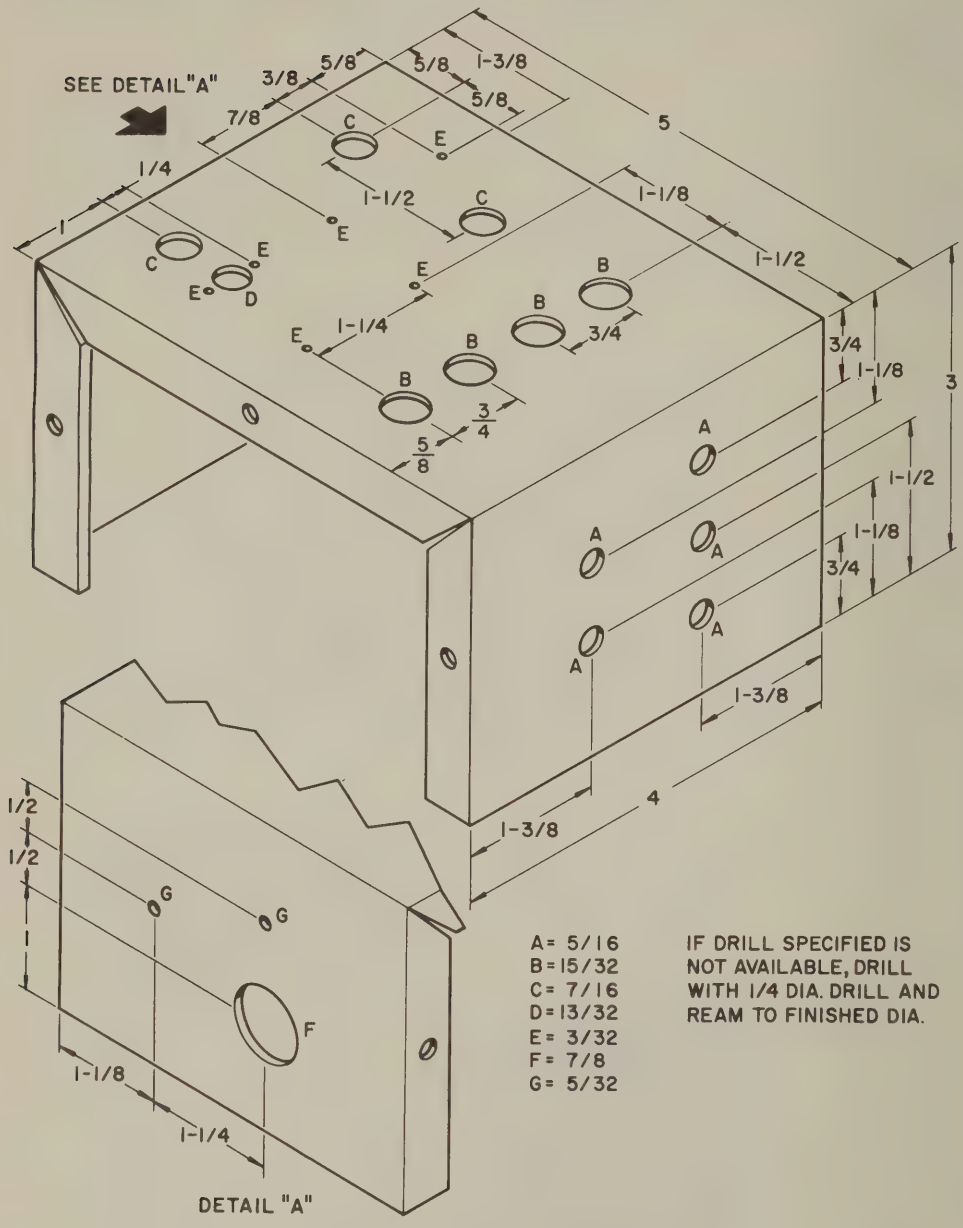


Fig. 33 — Photographs of the Kit Tester.



A= 5/16
B=15/32
C= 7/16
D=13/32
E= 3/32
F= 7/8
G= 5/32

IF DRILL SPECIFIED IS NOT AVAILABLE, DRILL WITH 1/4 DIA. DRILL AND REAM TO FINISHED DIA.

Chassis, 3x4x5-inch with cover, Minibox or equivalent
Battery Holder, Keystone No.182 or equivalent
Batteries, RCA VS034A or equivalent; 4 required
Binding Posts, E.F. Johnson No.111-101
or equivalent, 5 required
Fuse, ½ ampere, type 3AG
Fuse holder, 3AG Littelfuse or equivalent
Grommets, 7/16-inch O.D., rubber; 3 required
I_1, I_2 = lamps, General Electric No.1813 or equivalent; 2 required
I_3 = lamp, General Electric No.49 or equivalent
Lamp Sockets, Leecraft 2-07-1 or equivalent; 3 required
Power Cord, 3 wire, No.18 AWG
Strain relief, Heyco 7P or equivalent
Terminal Strip, H.H. Smith No.864 or equivalent
Terminal Strips, miniature, H.H. Smith No.1070 or equivalent; 2 required
Transistor Socket Elco No.05-3301 or equivalent
C_1 = 0.1 microfarad, 50 volts, ceramic
R_1 = 1000 ohms, 10 watts
R_2 = 10,000 ohms, ½ watt
R_3 = 680 ohms, ½ watt
R_4 = 68 ohms, ½ watt
S_1 = Switch, push button, Cutler Hammer No.8411K12
or equivalent
S_2 = SPST, toggle, 125 volts, 3 amperes
S_3 = DPDT, toggle, 125 volts, 6 amperes
S_4 = SPDT, toggle, 125 volts, 6 amperes
Hardware: 2-56 and 6-32 screws, nuts, and lockwashers

Fig. 34 — Drilling details for Kit-Tester chassis.

CIRCUIT OPERATION

This circuit consists of two parts, the battery-operated transistor and diode checker and the 120-volt SCR and diode checker. The circuits for both parts are shown in Fig. 35.

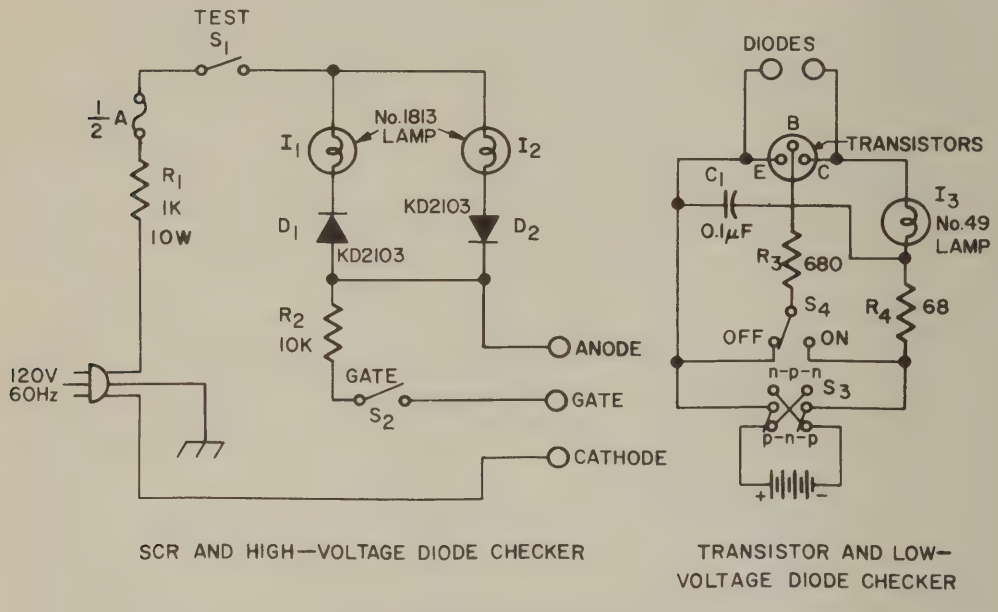


Fig. 35 — Schematic diagrams of Kit Tester.

Caution should be observed during testing of SCR's and high-voltage diodes because line voltage is applied across the units under test. Insulated test leads should be used during testing of SCR's. It should also be remembered that the case of the SCR is the anode and that it becomes "hot" under test. When the test button is depressed, the SCR or diode under test should not be handled.

The circuit for the transistor and diode checker is the same as that shown in Fig. 31 except that a DPDT switch is added so that the battery polarity can be reversed to test p-n-p or n-p-n transistors and to place a forward or reverse bias on a diode under test.

During testing of a transistor, operation of the Base-On-Off switch should turn the lamp on and off if the transistor is good. If the lamp remains on or off, the transistor is bad.

For testing of the low-voltage diode (KD2104), the diode terminals are used. It is not necessary to observe the polarity markings on the diode. If the diode is good, operation of the n-p-n/p-n-p switch will cause the lamp to turn on and off. If

the diode is "open", the lamp will not go on. If the diode is shorted, the lamp will stay on regardless of the position of the switch.

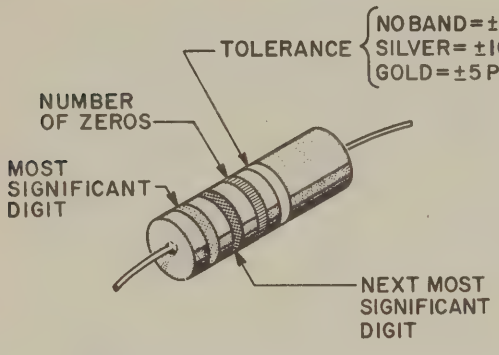
The two-transistor regenerative-switch subassembly shown in Fig. 26 may be checked with this circuit if it is connected to the diode terminals. A 1000-ohm resistor should be momentarily connected to the collector and emitter leads of the KD2101 transistor. If this connection does not cause the lamp to light and stay on, the n-p-n/p-n-p switch should be moved to the other position. If the lamp still does not light after the 1000-ohm resistor is momentarily connected to the collector and emitter leads of the KD2101 transistor, the regenerative-switch subassembly under test is bad. It is possible that a transient may be induced in the leads of the regenerative switch when it is connected to the diode terminals. The transient will cause the regenerative switch to trigger immediately. This undesirable switch effect can be eliminated by momentary operation of the n-p-n/p-n-p switch so that capacitor C_1 can absorb the transient. If the light remains on after this operation, the regenerative-switch subassembly under test is bad.

The SCR and diode test circuit uses two lamps as indicators; each lamp has a diode in series with it. When an SCR is connected to the test terminals, the lamps should not light when the "TEST" button is depressed because the SCR should not be conducting. When the gate switch is moved to the "on" position, the SCR should conduct in one direction only; this conduction is indicated by the lighting of only one lamp. If at any time during this test two lamps should light, the SCR is shorted; if neither lamp lights when the "TEST" button is pushed, the SCR is open.

During testing of the KD2103 high-voltage diode, only the anode and cathode terminals on the Kit Tester should be used; diode polarity does not have to be observed. If either lamp lights when the "TEST" button is pushed, the diode is good; if both lamps light, the diode is shorted; if both lamps remain off, the diode is open.

RESISTOR COLOR CODE

The value of a resistor is indicated by its colored stripes, as shown in Fig. 36. For example, a resistor showing four stripes that are yellow, black, green, and silver, respectively, from left



COLOR-NUMBER EQUIVALENTS FOR FIRST THREE BANDS

BLACK	= 0
BROWN	= 1
RED	= 2
ORANGE	= 3
YELLOW	= 4
GREEN	= 5
BLUE	= 6
VIOLET	= 7
GRAY	= 8
WHITE	= 9

Fig. 36 — Explanation of color code used on resistors.

to right is a 4-megohm resistor with a ±10-per-cent tolerance. A resistor with green, blue, and red stripes is a 5600-ohm resistor with a ±20-per-cent tolerance.

SAFETY PRECAUTIONS

The circuits in this Manual are designed to operate conveniently from conventional 120-volt ac household power. Much thought and care has been used to make these control circuits as safe as possible. However, certain precautions must be taken by the experimenter to ensure maximum safety.

Although three-wire input-power and output-load connectors are recommended and all the wiring and components are completely enclosed by the Minibox chassis, the chassis is not grounded unless the pigtail lead on the input plug is connected to the grounded housing of the 120-volt outlet. This plug should always be removed from the outlet when the cover is removed from the chassis. Even if the fuse has blown, the input terminal strip still carries potential when the input plug remains connected to the 120-volt outlet. If voltage readings are desired during troubleshooting precedures, the circuit may be energized; however, it must be remembered that the input-terminal strip, the case of the SCR, and other areas on the inside of the chassis carry dangerous voltages and should not be touched.

A good rule to follow during troubleshooting of an energized circuit is to keep one hand away from the chassis, in a pocket if possible. It is also recommended that troubleshooting never be undertaken alone. The use of safety glasses is recommended,

especially during soldering; solder splashes are painful and can be dangerous. Rings, bracelets, wristwatches, and the like should be removed during troubleshooting because they can be an electrical hazard.

AUXILIARY SENSOR KITS

Two auxiliary sensor kits are available for use with the **RCA Silicon Controlled Rectifier Experimenter's Kit KD2105.** The **Add-On Light-Sensor Experimenter's Kit KD2106** consists of one component, the ¼-inch-diameter broad-area cadmium-sulfide photoconductive cell shown in Fig. 37. Photocells of this type, which are also known as photoresistors or light-dependent resistors, utilize a polycrystalline photosensitive surface and are characterized by high sensitivity to visible radiation and moderate speed of response to changes in illumination. The resistance of

Fig. 37 — Photoconductive cell contained in RCA Add-On Light-Sensor Experimenter's Kit KD2106.

the cell decreases as the illumination level increases, as shown in Fig. 38.

The photocell can be conveniently connected to the circuit by use of a commercially available auto-radio antenna connector, with very little modification.* The photocell and an exploded view of the disassembled antenna connector are shown in Fig. 39. The only modification required in the connector is the drilling out of the brass insert in the black bushing nearest the photocell. In addition, the leads of the photocell should be covered with "spaghetti"-type insulation. These extra precautions eliminate the possibility of shorting the leads of the photocell.

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* This antenna connector is H. H. Smith No. 1300.

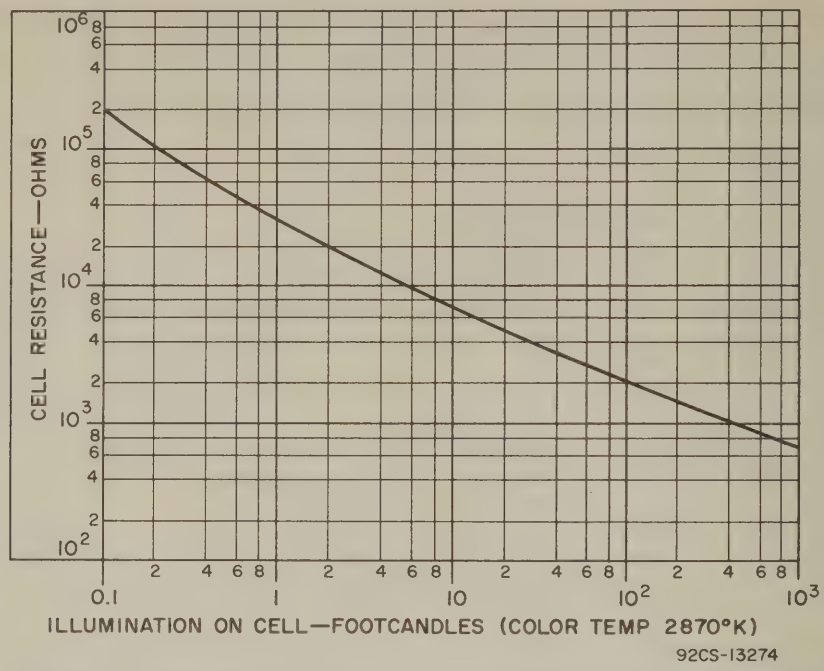


Fig. 38 — Resistance of photocell KD2106 as a function of illumination.

Fig. 39 also shows the completely assembled device ready for use. The connector P_1 is a standard Amphenol microphone connector and the lead is an insulated-shield microphone cable.

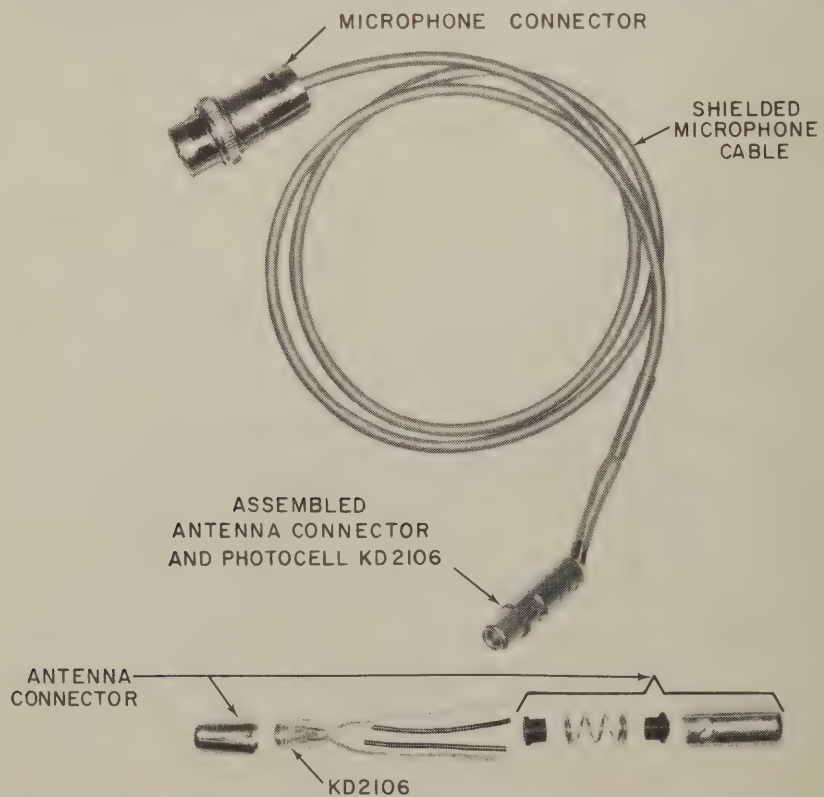


Fig. 39 — Photograph and exploded view of photocell-and-connector assembly.

The **RCA Add-On Heat-Sensor Experimenter's Kit KD2110** consists of three thermistors and about five inches of special tin-silver solder. (The melting point of the solder is higher than the maximum temperature of the highest-temperature-range thermistor, 150°C.) The thermistor is a solid-state device that has a very large, controlled, negative or positive resistance-temperature characteristic. This unique characteristic makes thermistors very useful for applications which interrelate thermal and electrical data. Fig. 40 shows resistance-temperature characteristics for the three thermistors included in the kit KD2110. These thermistors have a negative temperature coefficient. Additional thermistor data are shown in the table included in Fig. 41.

The solder contained in kit KD2110 is a rosin-cored type composed of 70 per cent lead, 27 per cent tin, and 3 per cent silver. Only solder containing silver can be used to attach leads or other connectors to the thermistors because the surfaces of these devices are coated with a silver compound. Any attempt to use ordinary lead-tin solder (not containing silver) will prove futile and will result in the removal or burning off of the silver coating.

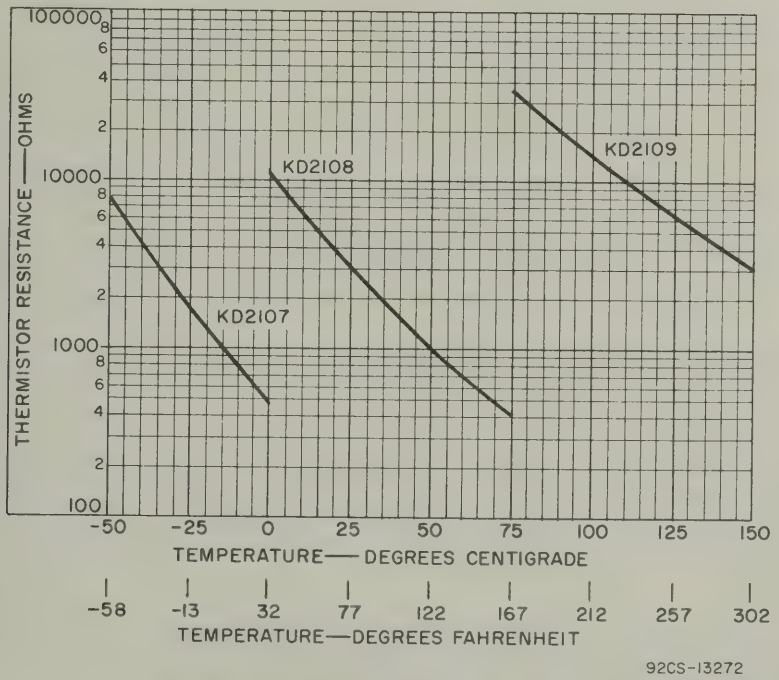
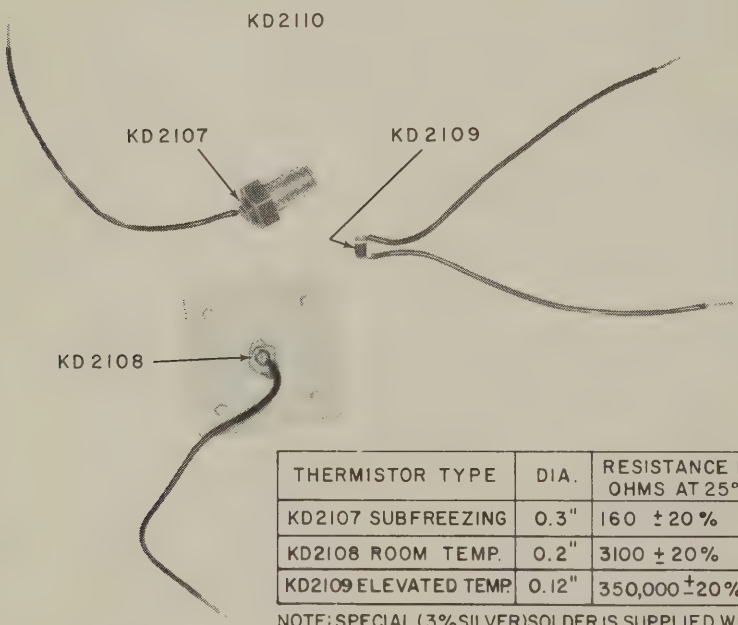


Fig. 40 — Resistance-temperature characteristics of thermistors contained in RCA Add-On Heat-Sensor Experimenter's Kit KD2110.

Fig. 41 shows one of the many possible mounting arrangements for each of the thermistors in kit KD2110. The procedure for mounting the thermistors as shown in the figure is as follows:

KD2107, the largest of the three thermistors in the kit, is soldered between a brass cap screw and a flexible lead. This type of mounting is useful at sub-freezing temperatures when one end of the thermistor is electrically connected to the frame or housing of the controlled device. Provisions for electrically insulating the cap screw from the controlled device must be made if this arrangement is used with the circuits shown in this Manual. The KD2107 is mounted on a large heat sink so that short-duration, locally directed heat currents do not cause premature triggering of an alarm circuit. (For example, in a freezer, it is not desirable to trigger the alarm each time the door is opened for food removal.)



THERMISTOR TYPE	DIA.	RESISTANCE IN OHMS AT 25° C	TEMP. RANGE °C
KD2107 SUBFREEZING	0.3"	160 ±20%	-50 TO 0
KD2108 ROOM TEMP.	0.2"	3100 ±20%	0 TO 75
KD2109 ELEVATED TEMP.	0.12"	350,000 ±20%	75 TO 150

NOTE: SPECIAL (3% SILVER) SOLDER IS SUPPLIED WITH KIT KD2110

Fig. 41 — Possible mounting arrangements for thermistors.

Thermistors, like transistors, are delicate devices; excessive heat or rough handling can damage them. For this reason, careful attention should be given to the following soldering techniques when leads or other adapters or connectors are connected to the KD2107:

1. The cap screw should be placed, head up, on an asbestos board or a sheet-metal pedestal held in a vise.

2. The cap screw should be heated by use of the small blue flame of a butane torch, and enough of the kit-supplied rosin-cored solder should be applied to form approximately a ¼-inch "puddle" on the top of the screw head; the heat should then be removed so that the puddle can solidify.

3. The cap-screw head should be reheated until the solder melts. The heat should then be removed and, by use of tweezers or long-nose pliers, the thermistor should be carefully dropped on the melted solder and pressed against the disc until the solder resolidifies. The flexible lead should then be attached to the top surface of the thermistor by use of a small-tip 50-to-100-watt soldering iron. Any lead-tin solder must be wiped away from the tip of the iron with a piece of waste or cloth before the following steps are taken.

4. The soldering iron and the lead end should then be "tinned" with the special solder.

5. The "tinned" surface of the soldering-iron tip should be placed on the thermistor, and a little solder should be applied to provide better heat conduction to the disc. Extra care is necessary at this point; too much heat will melt the solder between the thermistor and the cap screw and may appreciably alter the characteristics of the thermistor. When a puddle of solder forms between the soldering iron and the disc, the iron should be removed and the tinned end of the lead should be pressed lightly into the solder; the joint should then be blown on so that it cools quickly.

A similar procedure, using a torch and a soldering iron, should be used to mount the KD2108 thermistor; only a soldering iron is required to attach leads to the KD2109 thermistor. As mentioned at the beginning of this discussion, the mountings shown in Fig. 41 are merely suggested; any of the thermistors can also be mounted on the cap screw, the copper plate, or any convenient adapter.

The thermistor characteristics can change as much as 20 per cent as a result of the heat of the soldering iron. The original characteristics are restored, however, after the thermistor has been in use for several hours. Excessive heat can cause a wider change in characteristics and therefore requires a longer restoration period.

Circuits for the Experimenter

THIS section includes descriptions, photographs, and schematic diagrams for twenty-four practical circuits. Ten of these circuits are advanced, Twin-Kit circuits requiring two KD2105 kits. Three of the circuits use the photocell contained in kit KD2106; three other circuits use the thermistors contained in kit KD2110. Specifications for all other parts required are given in the parts list for each circuit.

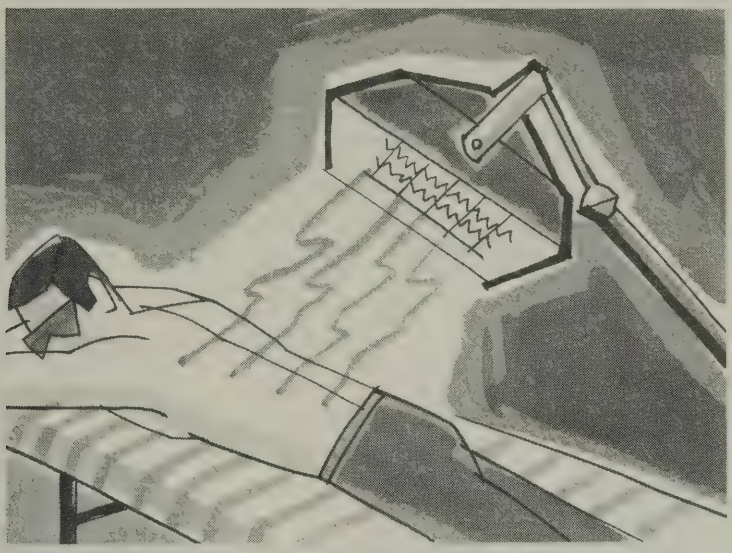
Single-Kit and Twin-Kit circuits are grouped by application. For example, under the heading of Lamp Dimmers will be found the description of the Single-Kit Lamp Dimmer circuit and the higher-power Twin-Kit Lamp Dimmer circuit. All data required by the experimenter to permit selection of the proper circuit for his application are given.

The circuits included in this Manual have been conservatively designed and are capable of excellent performance. However, performance depends as much on the quality of the components selected and the care employed in layout and construction as on the circuits themselves. Although wiring diagrams are not shown for the individual circuits, the photographs illustrate practical layouts that have provided excellent performance.

The voltage ratings specified for capacitors are the minimum dc working voltages required. Paper, mica, or ceramic capacitors having higher voltage ratings than those specified may be used except where the physical sizes of such capacitors may affect layout. However, if electrolytic capacitors having substantially higher voltage ratings than those specified are used, they may not "form" completely at the operating voltage, with the result that the effective capacitances of such units may be below their rated value. All capacitor values are given in microfarads and resistor values in ohms, unless otherwise noted.

The shaded areas on the schematic drawings identify those circuit components that are a part of the basic chassis.

LAMP DIMMERS



An application of a Lamp Dimmer circuit is to control the intensity of a heat lamp according to the dosage desired by the user.

The Lamp Dimmer circuits can be used to provide continuous and smooth control of the brightness of incandescent lamps. Lamp brightness can be adjusted from complete cutoff to essentially full rated value. The dimmer circuits are useful for providing the exact amount of light required at different times in various locations, e.g., in the nursery (full brightness when needed, just a bit as a "night light"), in the bedroom (full brightness for reading, dimmer for TV), in the family or living room (the desired level for any mood or occasion). Other applications include the control of power to heating pads and infrared heat lamps and to stage lighting of the type used in amateur productions.*

The Single-Kit dimmer can handle loads up to 240 watts; the Twin-Kit dimmer, because of its high power-handling capacity, can handle loads up to 660 watts. The lamp-dimmer circuits can control, in addition to lamps, the amount of power transmitted to heating devices and the speed of ac/dc universal motors.

The radio-frequency interference created by the dimmers can be minimized by use of the "L"-type filter described under **Adjustments and Special Considerations** for the Single-Kit dimmer.

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 1—Single-Kit Lamp Dimmer

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18); six additional resistors and one capacitor are mounted on the chassis as shown in Fig. 42. The line cord for the incandescent-lamp load is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

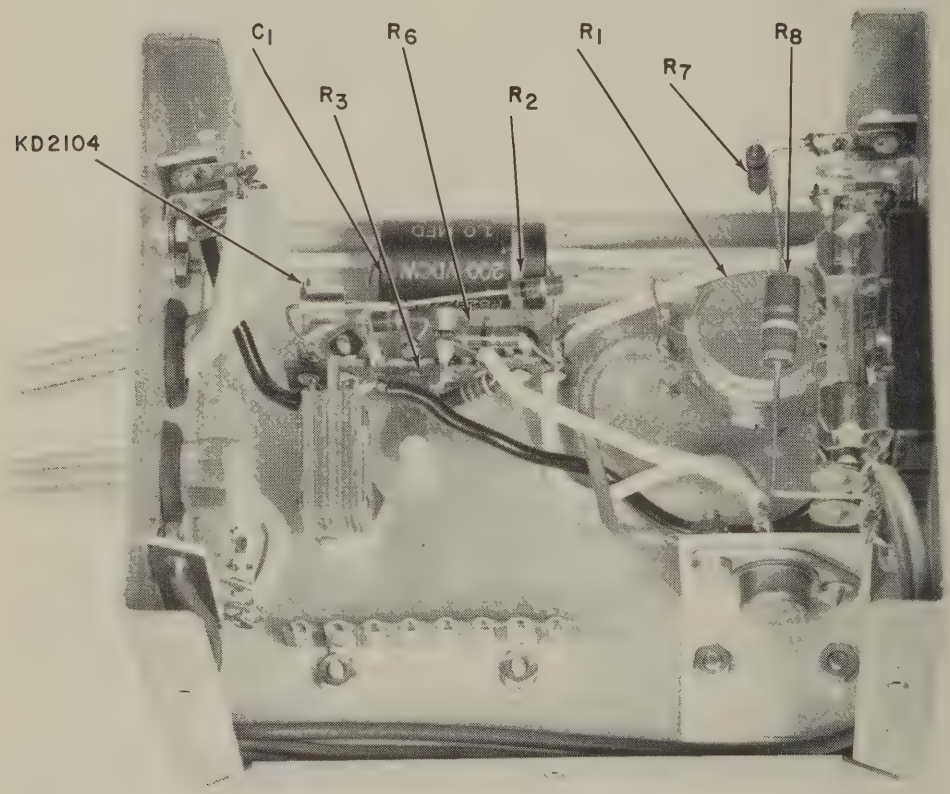


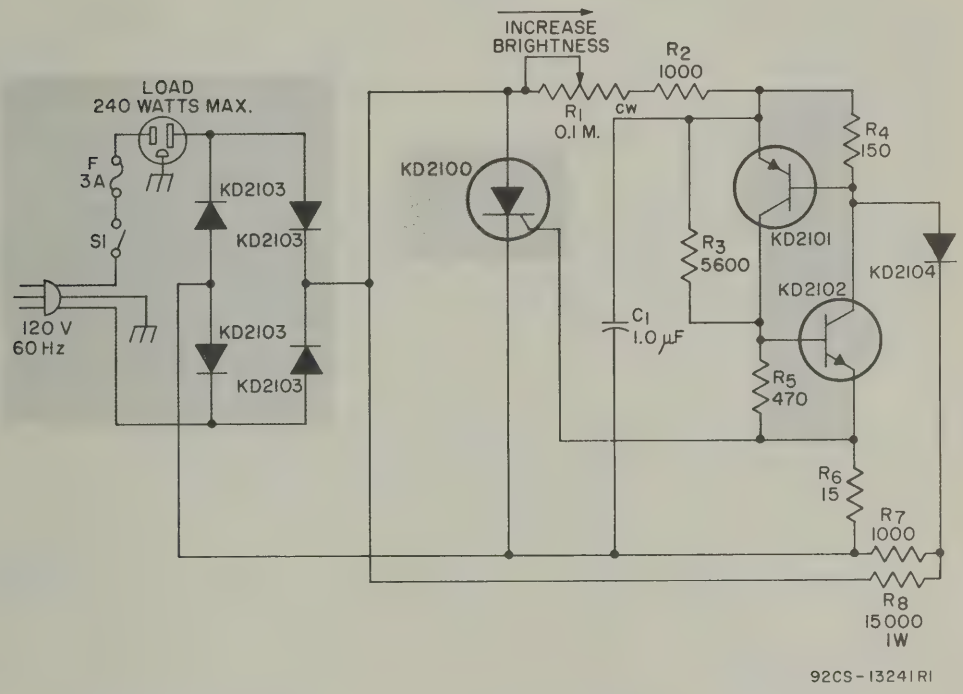
Fig. 42 — Photograph of Single-Kit Lamp Dimmer (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this lamp dimmer is shown in Fig. 43. The brightness of the incandescent-lamp load is determined by the time during each half-cycle of the ac input signal that the SCR KD2100 conducts. This time, in turn, is controlled by manual adjustment of the control knob, which varies the position of the arm on the potentiometer R_1.

When the potentiometer is connected as indicated in Fig. 43, R_1 is set for minimum resistance when the control knob is turned

to the furthest clockwise position. The capacitor C_1 then charges rapidly to the triggering potential of the two-transistor regenerative switch (preset to six volts for this circuit), and the switch is triggered into conduction early in each input half-cycle. When the transistors KD2101 and KD2102 start conducting, C_1 discharges through the series circuit of the transistors and the gate of the SCR KD2100. This discharge current triggers the SCR into conduction, and load current then flows until the end of the input half-cycle. This operation is repeated for each succeeding half-cycle of the ac input signal, and maintains the incandescent-lamp load at maximum brightness.



Basic chassis A (see Fig.17 for parts list)
C_1 = 1 microfarad, 200 volts, paper
R_1 = potentiometer, 100,000 ohms, 2 watts, linear
R_2, R_7 = 1000 ohms, ½ watt
R_3 = 5600 ohms, ½ watt
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 15 ohms, ½ watt
R_8 = 15,000 ohms, 1 watt

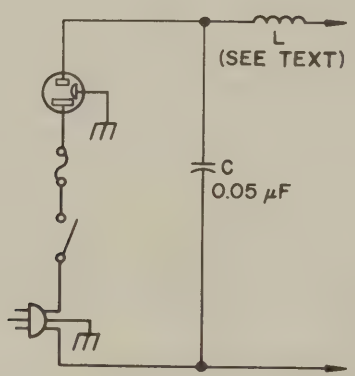
Fig. 43 — Schematic diagram of Single-Kit Lamp Dimmer.

As the control knob is turned counter-clockwise, the resistance of the potentiometer R_1 is increased. C_1 then charges more slowly, and the SCR is triggered later in the input half-cycle, or not at all if the charge on C_1 fails to reach six volts. Thus, the brightness of the lamp is reduced, or is turned off completely when R_1 is in the maximum counter-clockwise position.

The diode KD2104 is used to prevent improper timing of the circuit when R_1 is set high enough so that C_1 does not charge to six volts. At the end of each half-cycle, this diode triggers the transistor switch into conduction so that any residual charge in C_1 is discharged rapidly through the transistors and resistor R_6. This "anti-skip" circuit ensures that each half-cycle of operation starts under the same conditions and thus provides smooth, continuous operation. Resistor R_7 completes the conduction path for the "anti-skip" diode KD2104.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

It is possible that this lamp-dimmer circuit may produce some radio-frequency interference, particularly when it is adjusted for half-brightness. If this interference is objectionable, a simple L-filter such as that shown in Figs. 44 and 45 may be installed between the circuit and the voltage source and load to reduce the noise to a less objectionable level. The filter consists of about 18 feet of No. 18E wire "scramble" or random-wound on a 0.5-inch-diameter rod, and a 0.05-microfarad, 200-volt, paper capacitor connected as shown. If desired, the capacitor can be used as



C = 0.05 microfarad, 200 volts, paper
L = approximately 18 feet No.18E wire scramble wound on ½"dia. rod or on the capacitor (see text).

Fig. 44 — Schematic diagram of L-filter connections.

the core of the coil instead of the rod. If this method is used, a 600-volt capacitor should be used instead of a 200-volt type. The larger 600-volt capacitor is used only because it provides a better physical core size. For proper operation and protection of the circuit components, the load should be adjusted (with R_1 set for maximum brightness) so that the anode current of the SCR's does not exceed two amperes. Because the cold resistance of incandescent lamps is appreciably lower than the resistance at oper-

ating temperatures, the ammeter used to read the anode current should be short-circuited (or should have at least a ten-ampere range) until the lamp achieves full brightness; otherwise, the initial current surge may be enough to damage the meter.

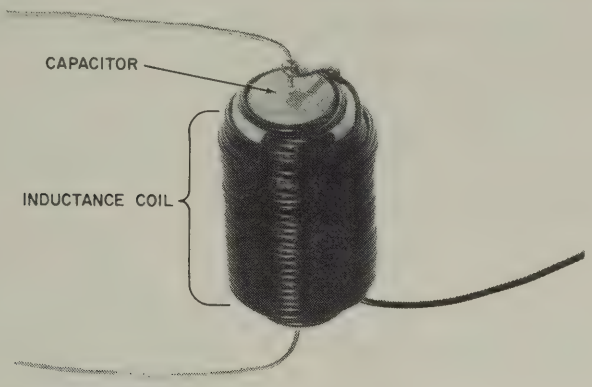


Fig. 45 — Photograph of L-filter used to reduce radio-frequency interference.

Fig. 46 shows typical waveshapes at pertinent points in the Single-Kit Lamp Dimmer circuit. The same curves apply when the L-filter is connected. These waveshapes are helpful in understanding the operation of the circuit, and are also a useful reference during trouble shooting.

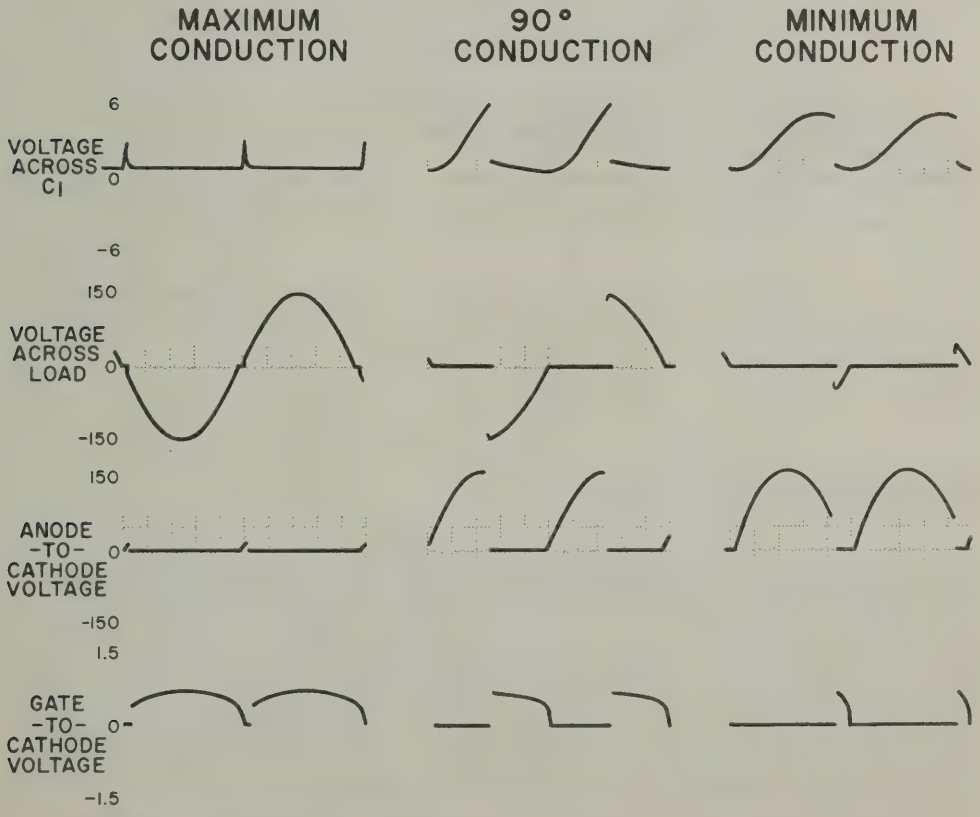


Fig. 46 — Typical waveshapes for Single-Kit Lamp Dimmer.

Circuit No. 2—Twin-Kit Lamp Dimmer

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Three additional capacitors and eight resistors are mounted on the chassis as shown in Fig. 47. The line cord for the load is plugged into the socket on the chassis. No additional holes are required in the chassis for this circuit.

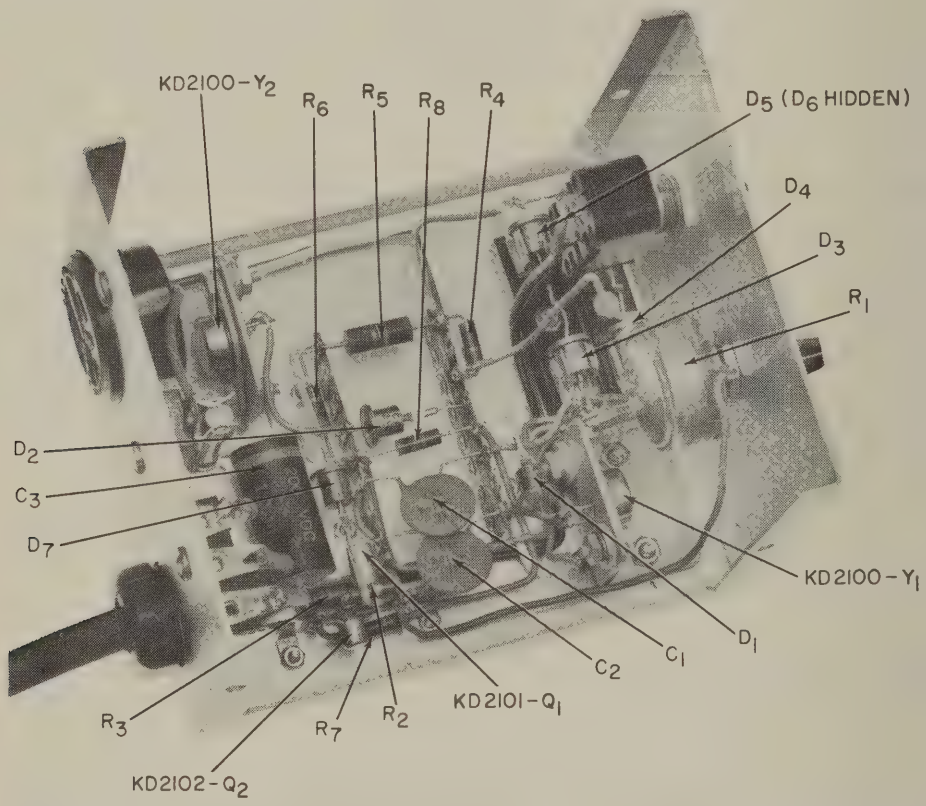
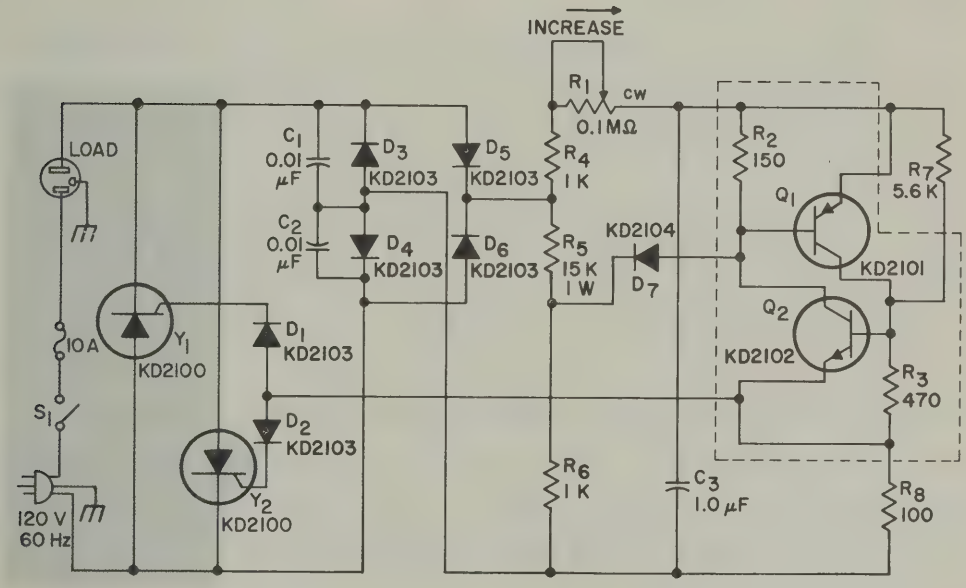


Fig. 47 — Photograph of Twin-Kit Lamp Dimmer (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this dimmer is shown in Fig. 48. The brightness of the incandescent-lamp load, the temperature of the heater element, or the speed of the universal motor being controlled is determined by the time during each half-cycle of the input signal that one of the KD2100 SCR's conducts. This time is controlled by adjustment of the control knob on the potentiometer R_1. The adjustment varies the position of the wiper arm on the potentiometer.

When the control knob on the potentiometer is turned to the furthest clockwise position, the potentiometer is set for minimum resistance, capacitor C_3 charges very rapidly, and the triggering-voltage level of the two-transistor regenerative switch is reached early in each half cycle. When regenerative-switch transistors KD2101 and KD2102 start conducting, C_3 discharges rapidly through the series circuit made up of the transistors and resistor R_8. This discharge current appears as a pulse across R_8 and the gate circuits of the SCR's, which are in parallel with R_8. If the anode of Y_1 is positive with respect to its cathode, the anodes of diodes D_3 and D_6 are also positive with respect to their cathodes and conduct, forming a conduction path between the junction of C_3 and R_8 and the cathode of Y_1. The pulse appearing across the parallel combination of R_8 and the Y_1 gate circuit (D_1, the gate, and C_1) causes Y_1 to conduct. At the same time the polarity



Basic chassis C (see Fig.20 for parts list)
Fuse holders, 3AG Littelfuse or equivalent, 2 required
Terminal strip, miniature, H.H. Smith No.1070
or equivalent
C_1, C_2 = 0.01 microfarad, 1000 volts, paper
C_3 = 1 microfarad, 200 volts, paper
R_1 = potentiometer, 100,000 ohms, 2 watt, linear
R_2 = 150 ohms, ½ watt
R_3 = 470 ohms, ½ watt
R_4, R_6 = 1000 ohms, ½ watt
R_5 = 15,000 ohms, 1 watt
R_7 = 5600 ohms, ½ watt
R_8 = 100 ohms, ½ watt

Fig. 48 — Schematic diagram of Twin-Kit Lamp Dimmer.

of Y_2, D_2, D_4, and D_5 is reversed (i.e., the anodes of these components are made negative with respect to their cathodes). As a result, these components do not conduct, and the pulse from R_8 is effectively prevented from reaching the gate of Y_2.

During the next half-cycle, the polarity of the power source reverses and Y_2 becomes the conducting SCR and Y_1 the nonconducting SCR. As the potentiometer control knob is turned counter-clockwise, the resistance of the potentiometer is increased and the time required to charge C_3 to the triggering potential of the two-transistor switch increases. As a result, the pulse is produced later in the half-cycle, or not at all if the charge on C_3 does not reach triggering level, and thus limits or cuts off the power to the load. The brightness of the lamp load, the temperature of the electric heater, or the speed of the universal motor, therefore, is controlled by a simple rotation of the potentiometer knob.

Diode D_7 is used to prevent improper timing of the trigger circuit when the potentiometer is set high enough so that C_3 does not charge to triggering voltage. At or very near the end of each half-cycle, D_7 triggers the transistor switch into conduction so that any residual charge in C_3 is dissipated. This "anti-skip" circuit composed of D_7 and R_6 ensures that each half-cycle of operation starts under the same conditions and provides smooth, continuous dimmer operation.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The adjustments and special considerations to be observed with the Twin-Kit Lamp Dimmer circuit are identical to those described for the Single-Kit Lamp Dimmer (Circuit No. 1).

UNIVERSAL MOTOR SPEED CONTROLS

An application of a Universal Motor Speed Control circuit is to vary the speed of a saber saw with varying loads and thus make it possible to work a wide variety of materials and realize longer blade life.

The Single-Kit and Twin-Kit circuits described here can be used to provide both speed control and speed regulation (constant speed under conditions of changing loads) for ac/dc universal motors (motors that are series wound).*

The Single-Kit circuit can control motors that have a nameplate rating or current requirement of 2 amperes; the Twin-Kit circuit is suitable for use with nameplate ratings up to 6 amperes. Motor speed can be adjusted from complete cutoff to essentially full rated value. The circuits also provide smooth anti-skip operation at reduced speeds. The Universal Motor Speed Control circuits are useful for adjusting and regulating the speed of power tools, such as drills, buffers, and jigsaws; hair dryers; floor polishers; and commercial food mixers. In addition, the Universal Motor Speed Controls may be used to regulate the speed of movie projectors and to rotate antennas such as those used by ham radio operators. When these circuits are used with a power drill, the speed of the motor can be made slow enough so that the drill can be used as a screwdriver.*

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 3—Single-Kit Motor Speed Control

CONSTRUCTION

This circuit uses the basic chassis A (shown in Figs. 17 and 18); nine additional resistors, two capacitors, and a silicon rectifier KD2104 are mounted on the chassis as shown in Fig. 49. The line cord for the power tool is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

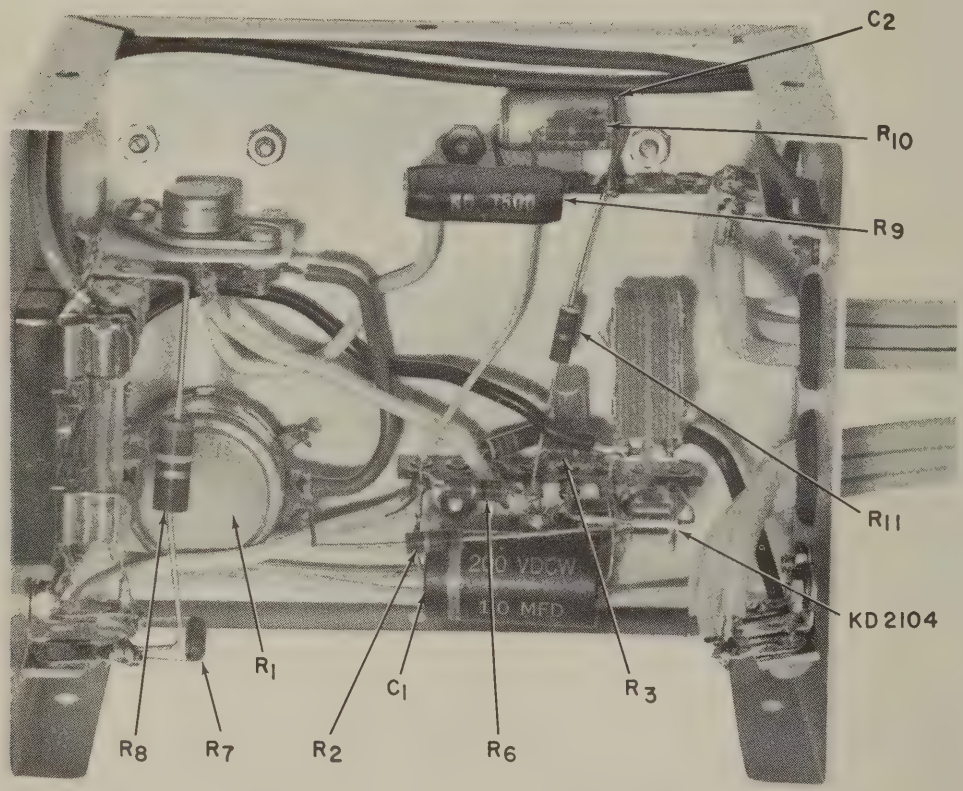
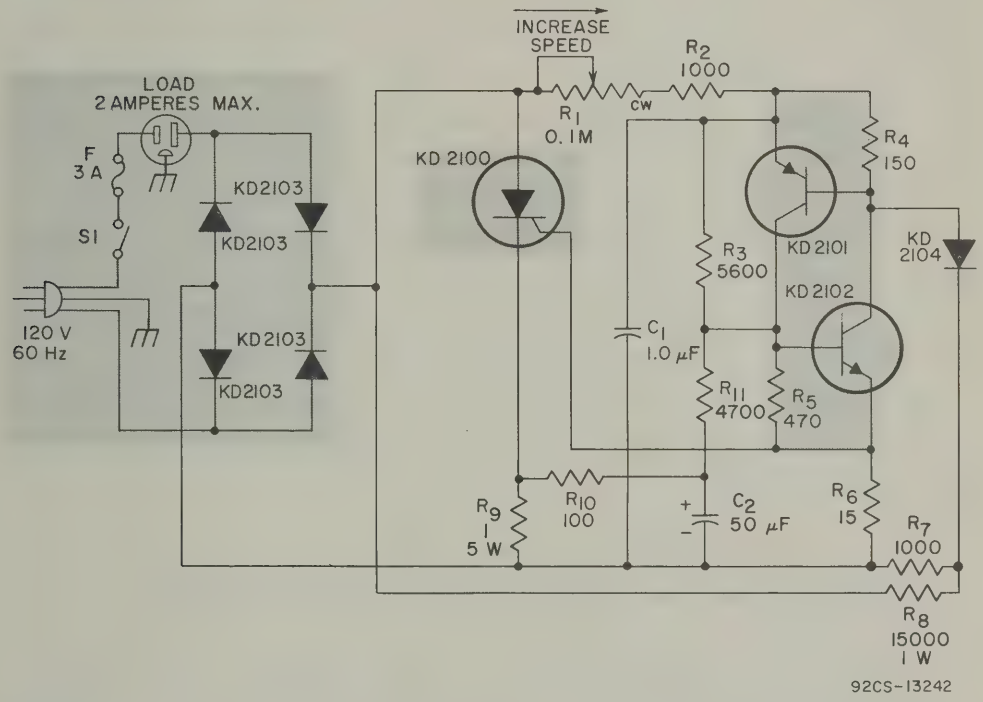


Fig. 49 — Photograph of Single-Kit Universal Motor Speed Control (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Single-Kit Universal Motor Speed Control is shown in Fig. 50. Except for the speed-regulation feedback circuit, this speed-control circuit operates exactly as the Single-Kit Lamp Dimmer, Circuit No. 1 (this circuit can also be used as a lamp dimmer, if desired). The speed of the power-tool motor is determined by the time during each half-cycle of the ac input signal that the SCR KD2100 conducts. This time, in turn, is controlled by manual adjustment of the control knob to vary the resistance of the potentiometer R_1.

When R_1 is set for minimum resistance, C_1 charges rapidly to the triggering potential of the two-transistor regenerative switch (preset to six volts for this circuit), and the switch is triggered into conduction early in each input half-cycle. When the transistors KD2101 and KD2102 start conducting, C_1 discharges through the series circuit of the transistors and the gate of the SCR KD2100. This discharge current triggers the SCR into conduction, and load current then flows until the end of the input half-cycle. This operation is repeated for each succeeding half-cycle of the ac input signal, and the motor is maintained at maximum speed.



Basic chassis A (see Fig.17 for parts list)
C_1 = 1 microfarad, 200 volts, paper
C_2 = 50 microfarads, 15 volts, electrolytic
R_1 = potentiometer, 100,000 ohms, 2 watts, linear
R_2, R_7 = 1000 ohms, ½ watt
R_3 = 5600 ohms, ½ watt
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 15 ohms, ½ watt
R_8 = 15,000 ohms, 1 watt
R_9 = 1 ohm, 5 watts
R_{10} = 100 ohms, ½ watt
R_{11} = 4700 ohms, ½ watt

Fig. 50 — Schematic diagram of Single-Kit Universal Motor Speed Control.

When the resistance of R_1 is increased, C_1 charges more slowly and the SCR is triggered later in the input half-cycle, or not at all if the charge on C_1 fails to reach six volts. Thus, the speed of the motor is reduced, or is cut off completely in the maximum-resistance position.

The diode KD2104 prevents improper timing of the circuit when R_1 is set high enough so that C_1 does not charge to six volts. At the end of each half-cycle, this diode triggers the transistor switch into conduction so that any residual charge in C_1 is discharged rapidly through the transistors and resistor R_6. Resistor R_7 completes the conduction path for the diode. This "anti-skip" circuit ensures that each half-cycle of operation starts under the same conditions, and thus provides smooth, continuous operation at reduced speeds.

The feedback circuit (R_9, R_{10}, R_{11}, and C_2) maintains essentially constant speed of the motor under changing load conditions. As load is applied to the motor, the speed momentarily decreases and the current through the motor and the SCR increases. Resistor R_9, in series with the SCR, develops an increased voltage drop which increases the charge on capacitor C_2. This increased charge produces a current increase through resistor R_{11}; less current is then required through resistor R_3, and the regenerative switch and the SCR are triggered earlier in the next half-cycle of the input voltage. The increased conduction time results in a corresponding increase in motor speed approaching that set by means of the potentiometer R_1. Resistor R_6 performs an additional function in this circuit, i.e., it shunts out commutator "hash" and thereby eliminates the possibility of premature triggering of the SCR.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

This circuit, like the Single-Kit Lamp Dimmer, may produce some radio-frequency interference; such interference can be minimized by use of the L-filter described previously in the **Adjustments and Special Considerations** for the Single-Kit Lamp Dimmer (Circuit No. 1).

Operation of single-speed motors at reduced speeds should be limited to relatively short periods. Most motors intended for single-speed operation depend on the air flow provided by a built-in fan to keep the temperature rise within acceptable limits. When the motor speed is reduced, this air flow also decreases, and the motor may become overheated.

In addition, operation at reduced speeds under appreciable loads should not be attempted without a dc ammeter in the anode circuit of the SCR. When the motor is maintained at essentially constant speed for an increased load, the current through

the motor and the SCR is increased to a higher level. Care should be taken to ensure that the anode current of the SCR does not exceed two amperes.

Only universal series-wound motors should be controlled with this circuit. The waveshapes shown in Fig. 46 are typical of those present at points of this circuit.

Circuit No. 4—Twin-Kit Motor Speed Control

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Two additional capacitors and eleven resistors are mounted on the chassis as shown in Fig. 51. The line cord for the load is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

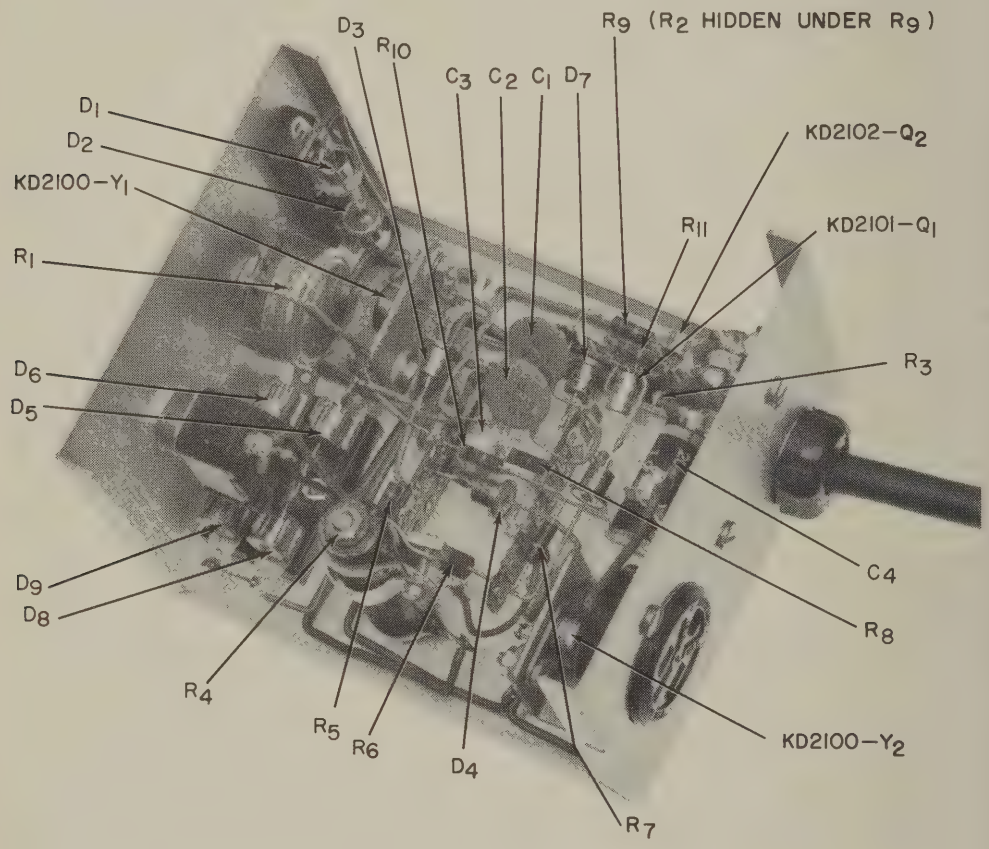
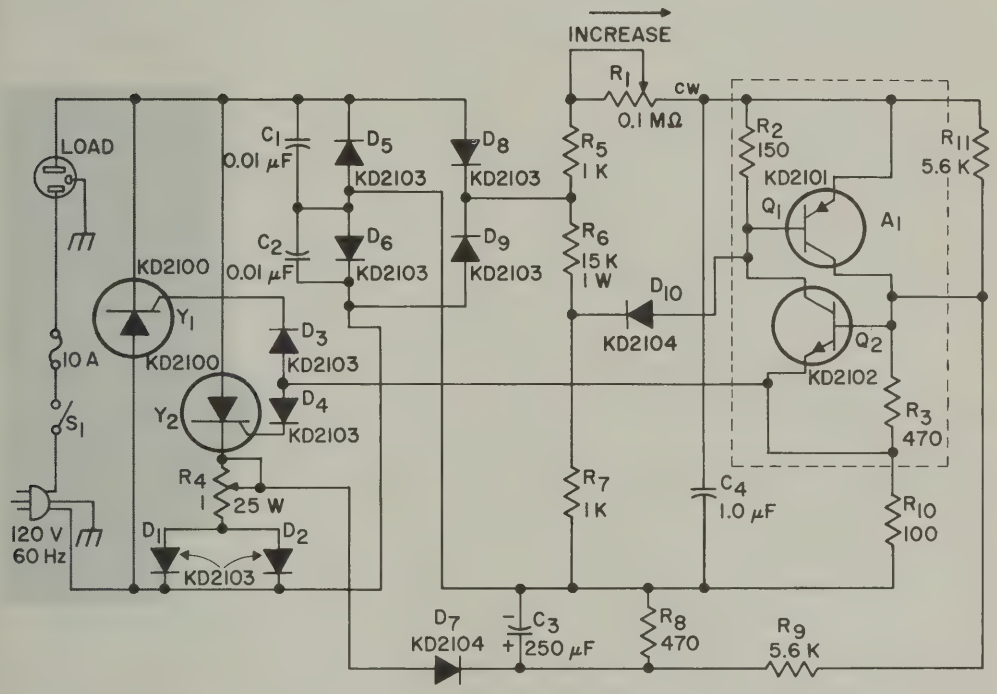


Fig. 51 — Photograph of Twin-Kit Universal Motor Speed Control (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for the Twin-Kit Motor Speed Control circuit is shown in Fig. 52. The speed of the universal motor is determined by the time that one of the KD2100 SCR's conducts during each half-cycle of ac input. This time is controlled by manual adjustment of the potentiometer.

When the potentiometer is set for minimum resistance (control knob in maximum clockwise position), capacitor C_4 charges very rapidly and the triggering-voltage level of the two-transistor regenerative switch A_2 is reached early in each half-cycle. When the transistors in the regenerative switch, KD2101 and KD2102, start conducting, capacitor C_4 discharges rapidly through the series circuit made up of the transistors and resistor R_{10} and causes a pulse across the parallel circuit composed of R_{10} and the gate circuits of the SCR's. If the anode of Y_1 is positive with respect to the cathode, the anodes of diodes D_5 and D_9 are also positive with respect to their cathodes and the diodes conduct.



Basic chassis C (see Fig.20 for parts list)
Fuse holders, 3AG Littelfuse or equivalent; 2 required
Terminal strip, miniature, H.H. Smith No.1070 or equivalent
C_1, C_2 = 0.01 microfarad, 1000 volts, ceramic
C_3 = 250 microfarads, 6 volts, electrolytic
C_4 = 1 microfarad, 200 volts, ceramic
R_1 = potentiometer, 100,000 ohms, 2 watts, linear
R_2 = 150 ohms, ½ watt
R_3, R_8 = 470 ohms, ½ watt
R_4 = 1 ohm, 25 watts, Ohmite No.0360 or equivalent
R_5, R_7 = 1000 ohms, ½ watt
R_6 = 15,000 ohms, 1 watt
R_9, R_{11} = 5600 ohms, ½ watt
R_{10} = 100 ohms, ½ watt

Fig. 52 — Schematic diagram of Twin-Kit Motor Speed Control.

A conduction path then exists between the junction of C_4 and R_{10} and the cathode of Y_1 through D_5. The pulse appearing across the parallel combination of R_{10} and the Y_1 gate circuit (D_3, the gate, and C_4) causes Y_1 to conduct. At the same time, Y_2 is non-conducting because its anode is negative with respect to its cathode; D_6 and D_8 are non-conducting for the same reason. Reverse polarity on Y_2 and D_6 and D_8 applies a reverse polarity to D_4 and prevents the pulse from R_{10} from reaching the Y_2 gate.

During the next half-cycle, the polarity of the power source reverses, and Y_2 becomes the conducting SCR and Y_1 the non-conducting SCR. This arrangement produces a unit capable of handling much more power than the single-kit motor control.

As the resistance of the potentiometer is increased, the time required to charge C_4 to the triggering potential of the regenerative switch A_2 becomes longer, and the pulse is produced later in the half-cycle, or not at all if the charge on C_4 does not reach triggering level. Therefore, the speed of the universal motor can be controlled by rotating the potentiometer knob.

When the mechanical load on the motor is increased, the motor demands more current. The increase in current causes an increase in voltage across the 1-ohm adjustable sensing resistor R_4. This voltage is fed back through diode D_7 and resistor R_9 to the base of the KD2102 transistor, one of the components of the regenerative switch. The application of this voltage to the base of the KD2102 reduces the triggering voltage required by the regenerative switch A_2 and causes it to conduct earlier in the half-cycle. Thus, more power is delivered to the motor so that it can maintain a constant speed. KD2103 diodes D_1 and D_2 prevent current from flowing through R_4 to the feedback network during the half-cycle in which Y_2 is not conducting. Resistor R_4 is set according to motor nameplate rating or load current; the proper setting for this resistor can be determnied from the curve shown in Fig. 53.

The KD2104 diode D_{10} is used to prevent improper timing of the triggering circuit when the potentiometer is set high enough so that C_4 does not reach triggering voltage. If the charge on C_1 has not reached triggering potential at the end of a half-cycle, this diode triggers the regenerative switch A_2 into conduction so that any residual charge in C_4 is dissipated. The "anti-skip" cir-

cuit composed of D_{10} and R_7 ensures that each half-cycle of operation starts under the same conditions and thus provides smooth, continuous motor operation.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The adjustments and special considerations for the Twin-Kit Motor Speed Control are identical to those described for the Single-Kit Motor Speed Control circuit.

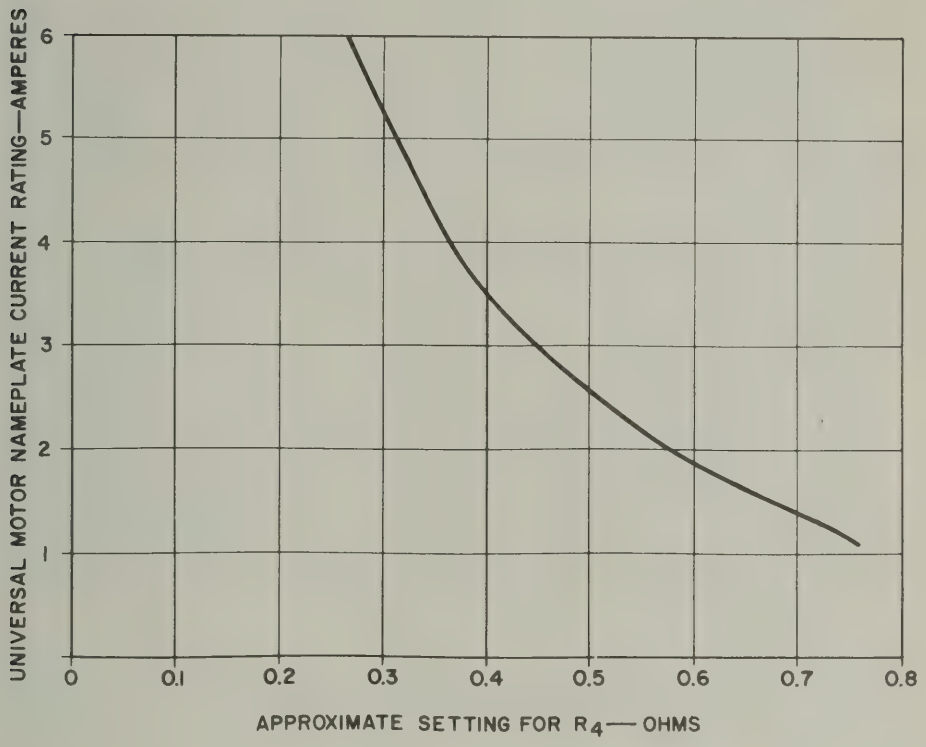
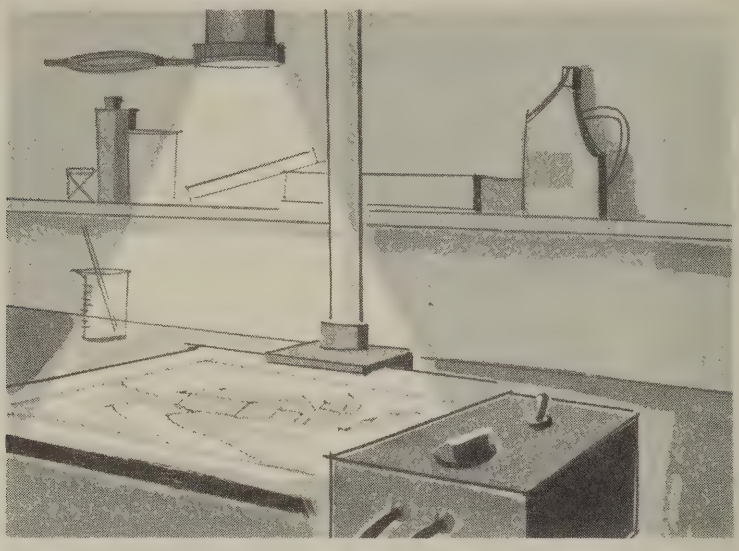


Fig. 53 — Approximate setting for R_4 for various motor nameplate ratings.

Circuit No. 5—Electronic Timer



An application of the Electronic Timer is to control enlarger exposure in the darkroom.

This circuit can be used as a kitchen or darkroom timer, as a game timer to signal the end of the period of time allowed for a player to act, or to turn off house lights after a certain time interval. The latter application is most useful for turning off yard lights after one has had time to leave the house, get into the car, and drive off.

The circuit is used to control the time interval between the application and interruption of power to ac/dc devices which do not use the frame as a ground and which have total power ratings up to 240 watts (nameplate current ratings up to two amperes). The interval between turn-on and turn-off can be adjusted from five seconds to approximately two minutes. This circuit is useful for providing controlled "ON" times for such equipment as photo-enlargers, developers, small heaters, incandescent lamps, and universal motors.*

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18); five additional resistors, two capacitors, a silicon rectifier KD2104, and a neon lamp are mounted on the chassis as shown

* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

in Fig. 54. The line cord for the equipment to be controlled is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

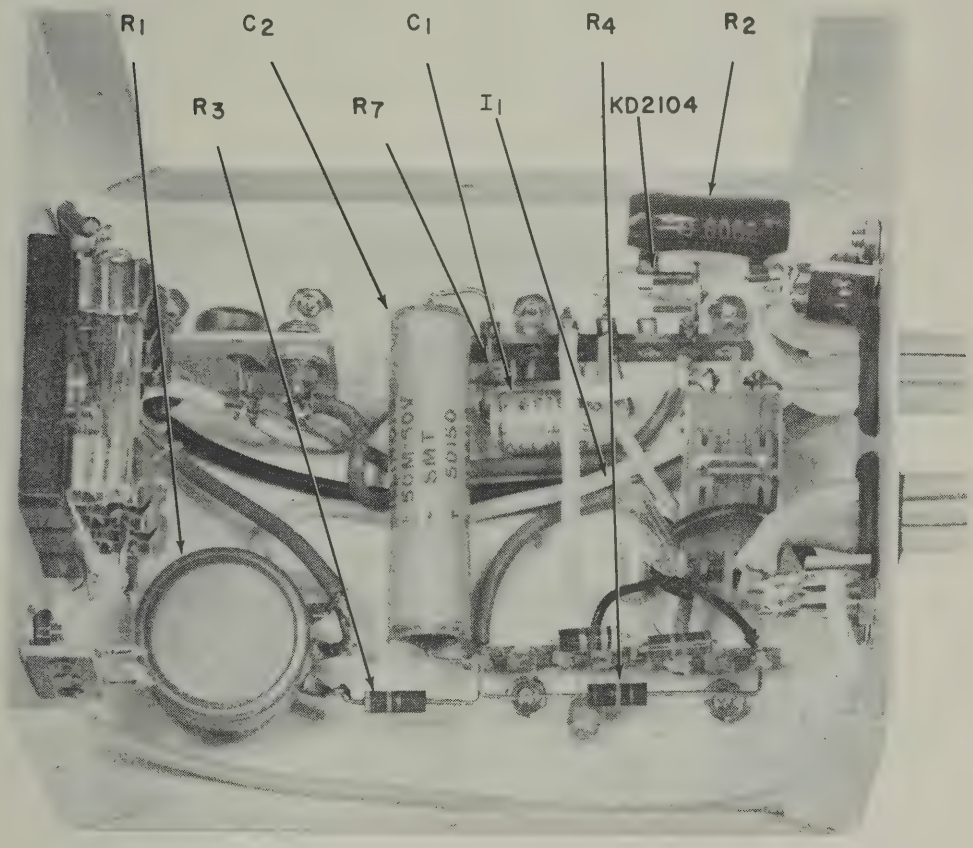
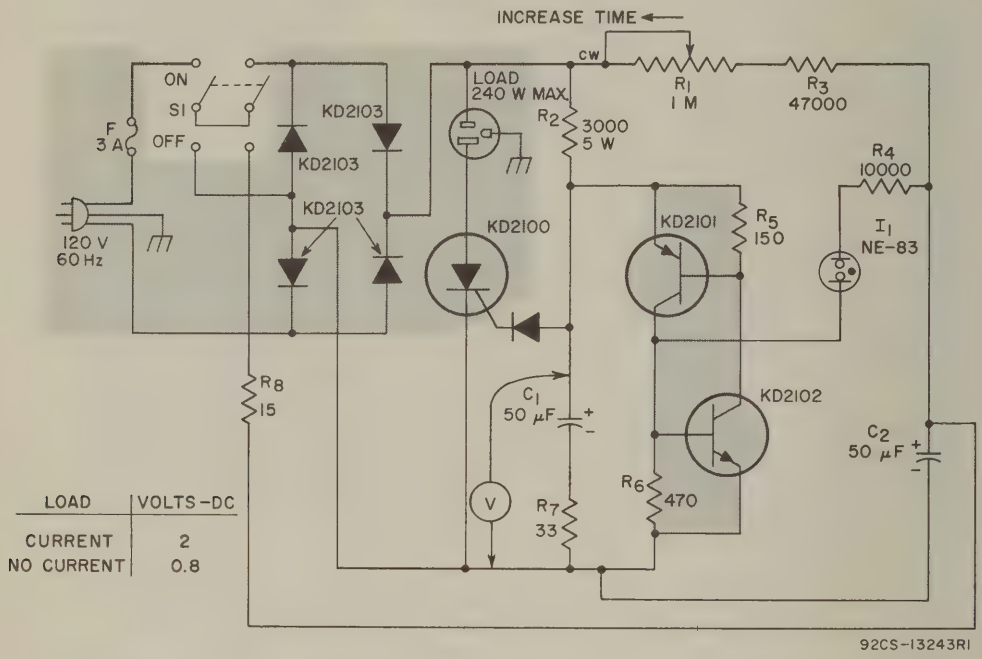


Fig. 54 — Photograph of Electronic Timer (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Electronic Timer is shown in Fig. 55. The "ON" time of the equipment with which this circuit is used is determined by the length of time required for the timing capacitor C_2 to charge to the value required to turn on the neon lamp NE-83 and trigger the two-transistor switch. This time, in turn, is controlled by adjustment of the control knob to vary the resistance of potentiometer R_1. When the double-pole double-throw (DPDT) on-off switch S_1 is turned to the ON position, the full-wave rectified current from the KD2103 silicon rectifiers charges capacitor C_1 through resistor R_2; the current from C_1 then flows through the diode KD2104 and triggers the SCR KD2100 into conduction to complete the load circuit.

At the same time, however, capacitor C_2 charges, at a rate determined by its capacitance and the series combination of R_1 and R_3, to a value of about 80 volts; at this point, the neon lamp NE-83 fires and the current through the lamp activates the two-transistor regenerative switch. When transistors KD2101 and KD2102 become saturated, they provide a discharge path for C_1, and the capacitor discharges through resistor R_7 and the two transistors to approximately one volt (the drop across the transistors). Current then ceases to flow in the gate circuit of



Basic chassis A (see Fig.17 for parts list)
C_1 = 50 microfarads, 15 volts, electrolytic
C_2 = 50 microfarads, 150 volts, electrolytic
I_1 = lamp, neon, General Electric NE-83 or equivalent
R_1 = potentiometer, 1 megohm, 2 watts, linear
R_2 = 3000 ohms, 5 watts
R_3 = 47,000 ohms, ½ watt
R_4 = 10,000 ohms, ½ watt
R_5 = 150 ohms, ½ watt
R_6 = 470 ohms, ½ watt
R_7 = 33 ohms, ½ watt
R_8 = 15 ohms, ½ watt
S_1 = Switch, DPDT, toggle, 3 amperes, 125 volts; replaces SPST switch on basic chassis A.

Fig. 55 — Schematic diagram of Electronic Timer.

the SCR, and KD2100 is not triggered on the next half-cycle of input voltage. As a result, the load circuit is not completed and no power is delivered to the load until the circuit is reset. The diode KD2104 increases the threshold voltage of the SCR gate

circuit from 0.6 volt (the drop across the gate-cathode junction of the SCR) to 1.2 volts; thus it prevents accidental triggering of the SCR and improves the stability of the circuit.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

With the values shown in Fig. 55 for R_1, R_3, and C_2, this circuit can be set for intervals of time from five seconds to approximately two minutes by adjustment of the potentiometer R_1. Although longer time intervals can be obtained by the use of a larger value for the timing capacitor C_2, it is not economically feasible to control intervals of much more than five minutes with this circuit.

The exact length of the timing interval will depend on the actual capacitance of C_2. Most electrolytic capacitors are rated on the basis of minimum guaranteed value (MGV), and the capacitor used may have a value much higher than its rating. The circuit should be calibrated for various positions of the control knob after the timing capacitor has had a chance to age. Once the capacitor has reached its stable value, the precision of this timer should be well within the requirements of photographic and similar applications.

Circuit No. 6—Electronic Time Delay

This circuit is useful for actuating an auditory device to signal the end of a time interval (e.g., to limit card or chess players to one minute of "thinking time"), or for making another device "wait" for a short time until some action can be accomplished (e.g., getting into the picture before the camera clicks or assuring that, in an electrical circuit, the electrode voltages are applied after the heater voltage).

The circuit is used to delay the application of power to a load for a predetermined period after the control switch is turned on. Like the Electronic Timer (Circuit No. 5), it can be used with ac/dc devices that do not use the frame as a ground and that have total power ratings up to 240 watts (nameplate current ratings up to two amperes). The delay time can be adjusted from five seconds to approximately two minutes.*

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18); seven additional resistors, two capacitors, and a neon lamp are mounted on the chassis as shown in Fig. 56. The line cord for the equipment to be controlled is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

CIRCUIT OPERATION

The schematic diagram for this Electronic Time Delay is shown in Fig. 57. The delay time of the equipment with which this circuit is used is determined by the length of time required for the timing capacitor C_2 to charge to the value required to turn on the neon lamp NE-83 and trigger the two-transistor switch. This time, in turn, is controlled by adjustment of the control knob to vary the resistance of potentiometer R_1.

When the switch S_1 is turned to the ON position, the full-wave rectified current from the KD2103 bridge circuit charges capacitor C_1 through resistor R_2. The charge on C_1 is held to a peak potential of less than seven volts by the voltage divider formed by resistors R_2 and R_7. At the same time, the timing capacitor C_2 starts to charge through resistors R_1 and R_3 in series. When the charge on C_2 reaches a value of about 80 volts, the neon lamp NE-83 fires and triggers the two-transistor switch.

* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

When the transistors KD2101 and KD2102 become saturated, they complete the gate circuit through resistor R_8 and trigger the SCR into conduction. The fixed charge in C_1 then maintains conduction in KD2100, and load current continues to flow for

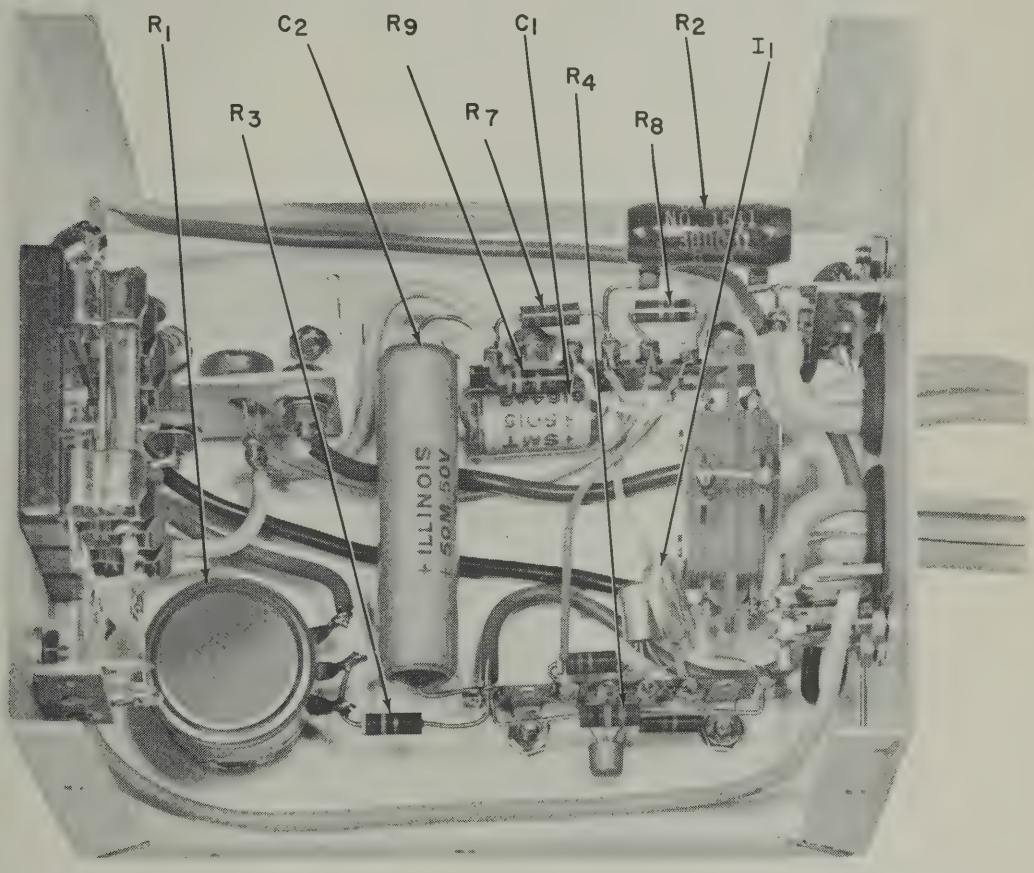


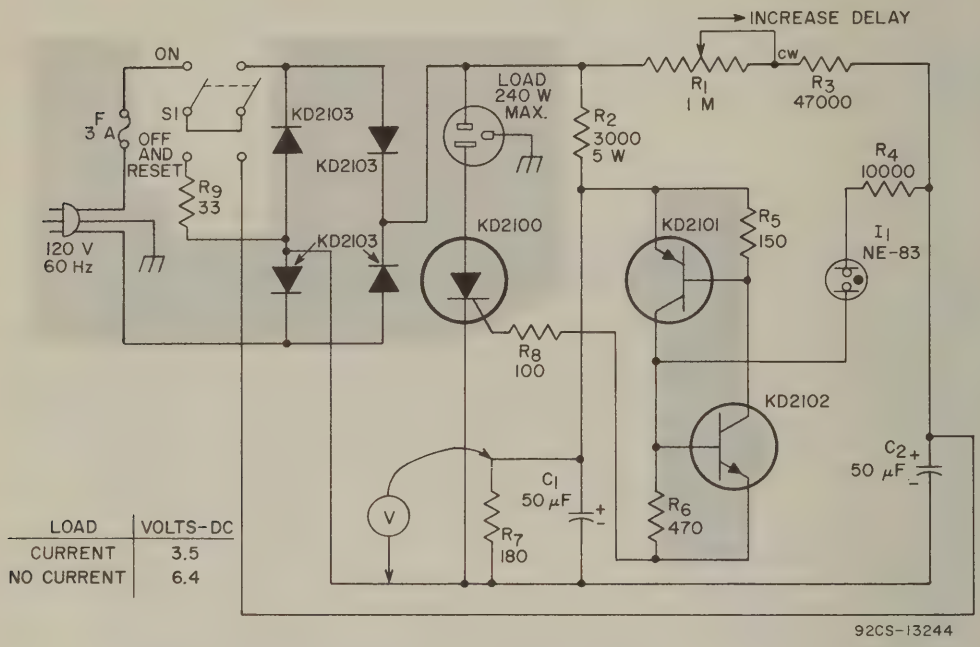
Fig. 56 — Photograph of Electronic Time Delay (call-outs indicate components added to basic chassis).

practically 180 degrees of each succeeding half-cycle of input voltage until S_1 is turned to the OFF position. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied as a result of the steady potential on C_1.) In the OFF position, S_1 discharges C_2 through resistor R_9 and prepares the circuit for the next time-delay application.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

With the values shown in Fig. 57 for R_1, R_3, and C_2, this circuit can be set for time delays from five seconds to approximately two minutes by adjustment of the potentiometer R_1.

Although longer time delays can be obtained by the use of a larger value for the timing capacitor C_2, it is not economically feasible to obtain delays of much more than five minutes with this circuit.

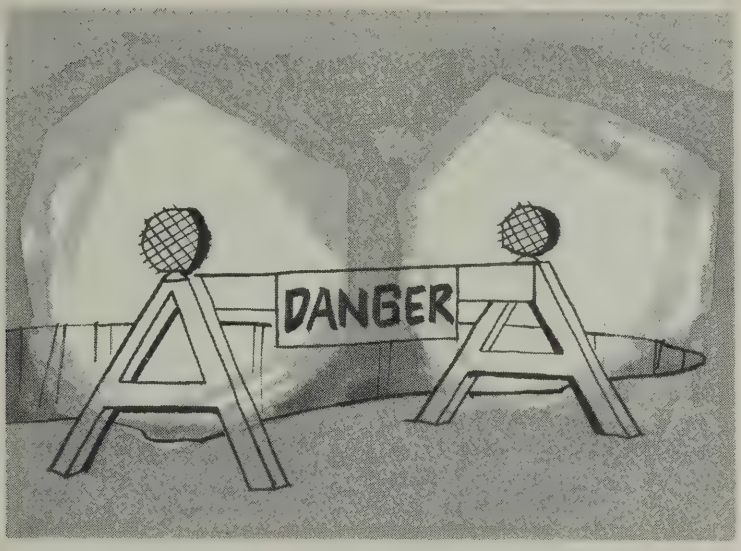


Basic chassis A (See Fig.17 for parts list).
C_1 = 50 microfarads, 15 volts, electrolytic
C_2 = 50 microfarads, 150 volts, electrolytic
I_1 = lamp, neon, General Electric NE-83 or equivalent
R_1 = potentiometer, 1 megohm, 2 watts, linear
R_2 = 3000 ohms, 5 watts
R_3 = 47,000 ohms, ½ watt
R_4 = 10,000 ohms, ½ watt
R_5 = 150 ohms, ½ watt
R_6 = 470 ohms, ½ watt
R_7 = 180 ohms, ½ watt
R_8 = 100 ohms, ½ watt
R_9 = 33 ohms, ½ watt
S_1 = switch, DPDT, toggle, 3 amperes, 125 volts; replaces SPST switch on basic chassis A.

Fig. 57 — Schematic diagram of Electronic Time Delay.

The exact length of the time delay will depend on the actual capacitance of C_2. Most electrolytic capacitors are rated on the basis of minimum guaranteed value (MGV), and the capacitor used may have a value much higher than its rating. The circuit should be calibrated for various positions of the control knob after the timing capacitor has had a chance to age. Once the capacitor has reached its stable value, the precision of this timer should be well within the requirements of most applications.

Circuit No. 7—Electronic Flasher



An application of the Electronic Flasher is to make warning lights more obvious and thus increase safety on the highway.

The circuit is used to supply power in short on-off pulses to ac/dc devices that have total power ratings up to 240 watts (nameplate current ratings up to two amperes) and that do not use the frame as a ground. The time of each "ON" pulse is fixed at approximately one-half second. The time of each "OFF" pulse can be adjusted to provide the desired number of "ON" pulses per minute.

This circuit is useful for controlling the flashing of incandescent-lamp loads (e.g., in Christmas-tree decorations, advertising signs, warning signals and flashing tower lights) and for actuating an auditory device to provide an intermittent signal (e.g., a metronome).*

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

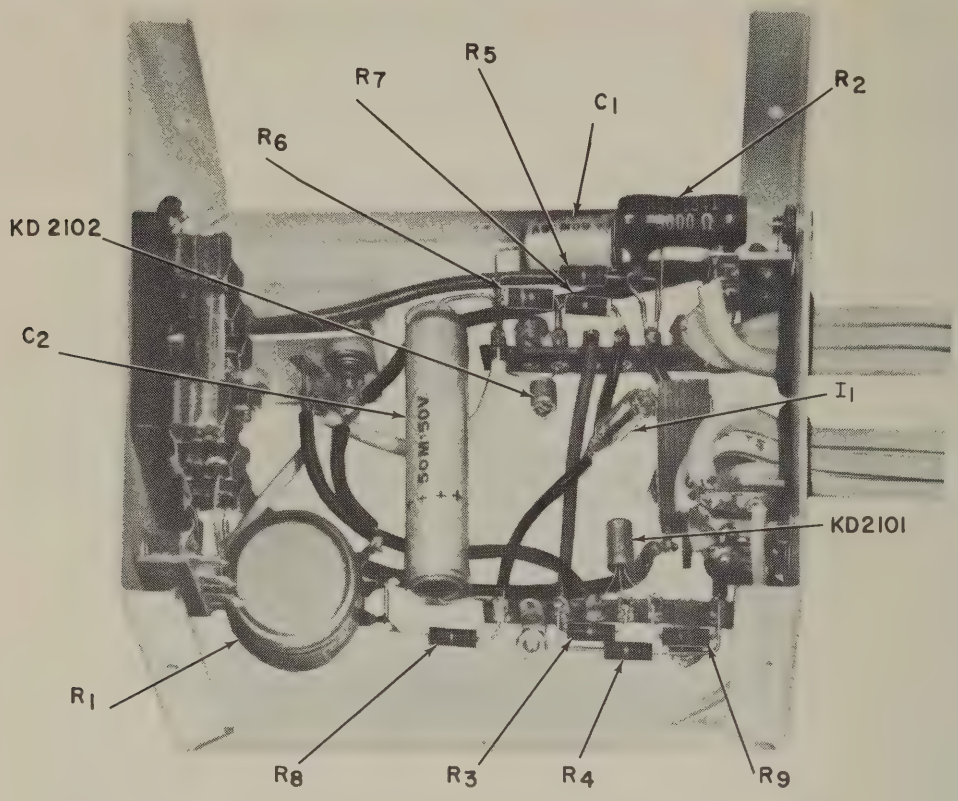


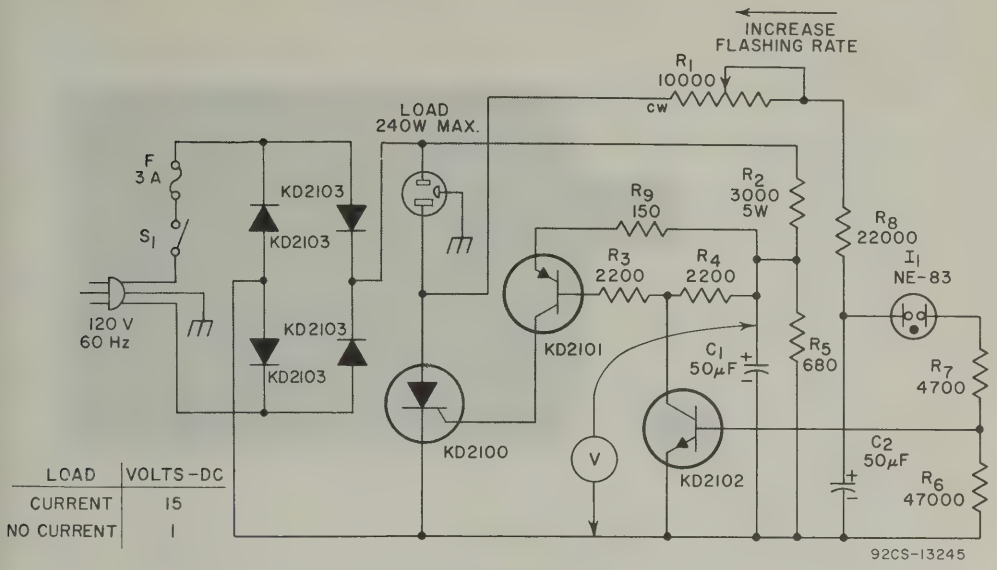
Fig. 58 — Photograph of Electronic Flasher (call-outs indicate components added to basic chassis).

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18), except that the two transistors are not used in the regenerative switch subassembly, but as a two-stage amplifier. Nine resistors, two capacitors, the two transistors KD2101 and KD2102, and a neon lamp are mounted on the chassis as shown in Fig. 58. The line cord for the equipment to be controlled is plugged into the socket connected to the chassis. No additional holes are required in the chassis for this circuit.

CIRCUIT OPERATION

The schematic diagram for the Electronic Flasher is shown in Fig. 59. The rate of the power pulses delivered to the equipment with which this circuit is used (or the length of time between "ON" periods) is determined by the time required to charge the timing capacitor C_2 to the value required to turn on the neon lamp NE-83. This time, in turn, is controlled by adjustment of the control knob to vary the resistance of potentiometer R_1.



Basic chassis A (See Fig.17 for parts list).
C_1 = 50 microfarads, 15 volts, electrolytic
C_2 = 50 microfarads, 150 volts, electrolytic
I_1 = lamp, neon, General Electric NE-83 or equivalent
R_1 = potentiometer, 10,000 ohms, 2 watts, linear
R_2 = 3000 ohms, 5 watts
R_3, R_4 = 2200 ohms, ½ watt
R_5 = 680 ohms, ½ watt
R_6 = 47,000 ohms, ½ watt
R_7 = 4700 ohms, ½ watt
R_8 = 22,000 ohms, ½ watt
R_9 = 150 ohms, ½ watt

Fig. 59 — Schematic diagram of Electronic Flasher.

When switch S_1 is closed, the pulsating dc voltage from the KD2103 bridge rectifier circuit is applied across the load and the parallel combination of the SCR KD2100 and the resistance-capacitance circuit R_1, R_8, and C_2. Because the SCR is not conducting, load current is negligible. Therefore, the input pulses charge C_2, through resistors R_1 and R_8, to the firing potential of the neon lamp NE-83, which is about 80 volts. When the neon lamp fires, the current through resistor R_7 (approximately two milliamperes) serves as the input signal to the base of the transistor KD2102.

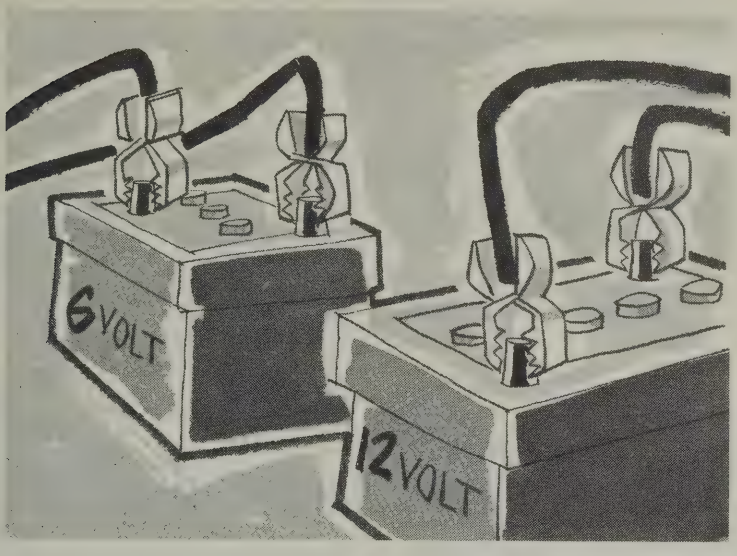
The transistors KD2101 and KD2102 are used in this circuit as a two-stage amplifier rather than as a regenerative switch. Resistor R_6 in the base-emitter circuit of KD2102 ensures that the transistors remain cut-off when NE-83 is not conducting. The output from the two-stage amplifier triggers the SCR into conduction, and the full pulsating dc input then appears across

the load (the SCR is a short circuit across R_1, R_8, and C_2). Load current continues to flow for practically 180 degrees of each succeeding half-cycle of input signal until C_2 discharges to the extinction voltage of the NE-83. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied to the transistors as a result of the stored energy in capacitor C_1.) When the charge on C_2 is insufficient to maintain conduction in the neon lamp NE-83, there is no input to the two-stage transistor amplifier, gate current to the SCR ceases, and the SCR is not triggered into conduction on the next half-cycle of input. The load current then drops to a negligible value, and the operating cycle starts again.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The rate of discharge for C_2, and therefore the "ON" time for the flasher, is controlled by the value of resistor R_7; the value shown in Fig. 59 provides an "ON" pulse of approximately one-half second. The charging rate for C_2, and therefore the "OFF" time for the flasher, is controlled by means of potentiometer R_1. For warning-signal applications, R_1 is normally adjusted to provide 40 flashes per minute, with an "ON" time of one-half second and an "OFF" time of one second. Resistors R_2 and R_5 and capacitor C_1 constitute the power supply for the two-stage transistor amplifier; R_9 is a current-limiting resistor for transistor KD2101.

BATTERY CHARGERS



The Battery Charger circuits can be used to keep 6- and 12-volt batteries at full charge.

The three Battery Charger circuits described below are especially useful for recharging run-down batteries in automobiles, boats, trailers, or other vehicles without removing them from their original mounting and without need for constant attention. The Single-Kit circuits are particularly useful in emergency lighting systems because their "trickle" charge capability keeps the emergency batteries up to full charge at all times.

Two of the chargers can be built with single kits on a basic chassis, while the third requires two kits and a special chassis. The advantage of the twin-kit, 12-volt battery charger is its higher charging rate of 5 amperes. The single-kit 6-cell, 12-volt battery charger charges at a rate of 2 amperes; the single-kit 3-cell, 6-volt battery charger charges at a rate of 3.2 amperes. Both single-kit chargers switch automatically from charging current to a "trickle" charge when the battery is fully charged. The twin-kit charger turns off automatically when the full charge condition exists. In all cases, an indicator lamp lights when the battery reaches full charge.*

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 8—Single-Kit Battery Charger (6 cell, 12 volts)

CONSTRUCTION

The circuit uses the basic chassis B (shown in Fig. 19); four additional resistors, one capacitor, a silicon rectifier KD2104, and an indicator lamp are mounted on the chassis as shown in Fig. 60. The battery is connected as shown in Fig. 61. No additional holes are required in the chassis for this circuit.

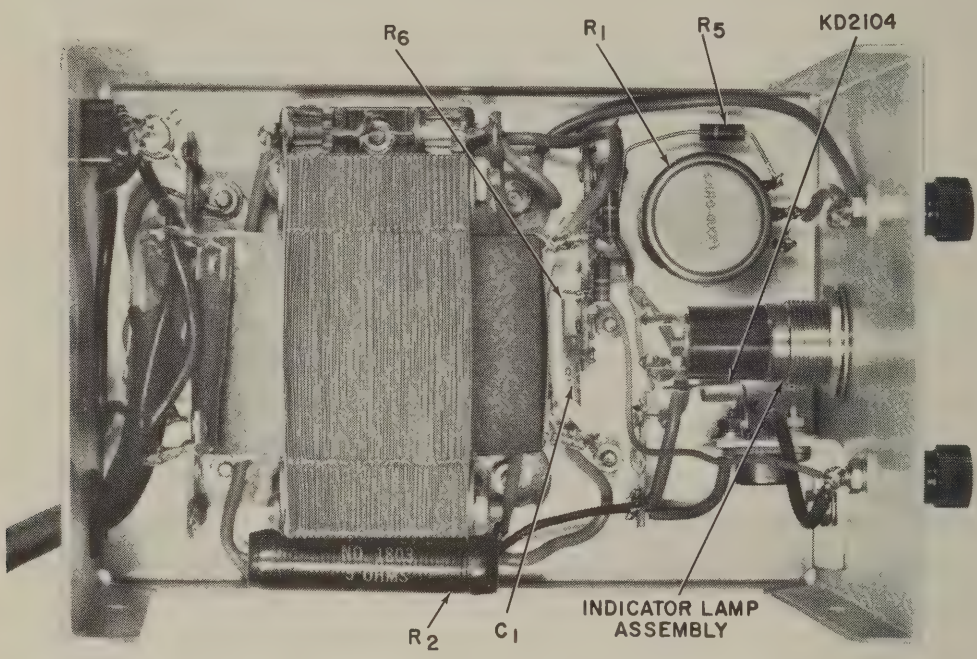


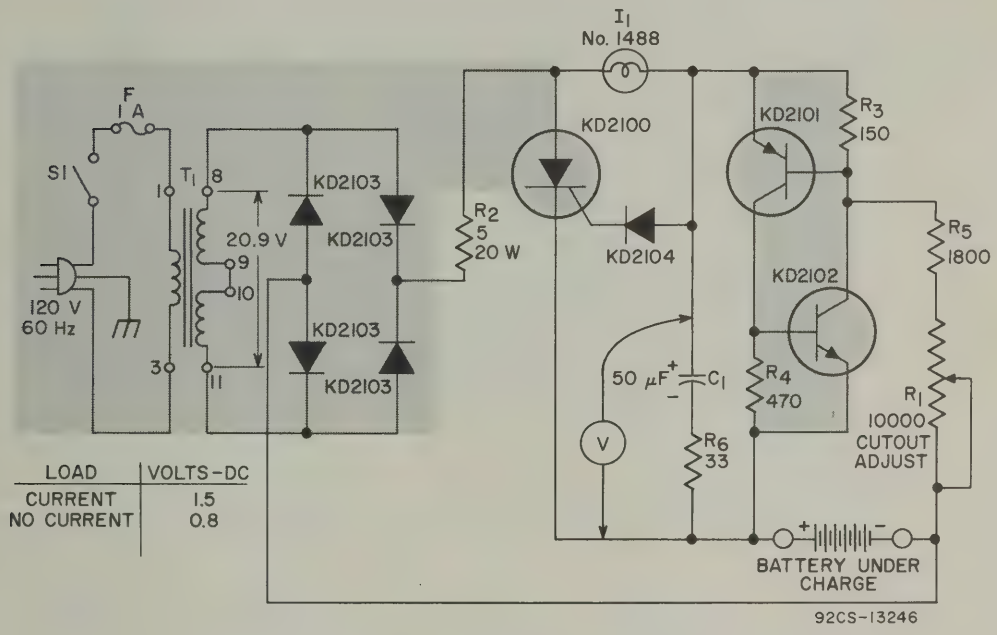
Fig. 60 — Photograph of Single-Kit 12-Volt Battery Charger (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this 12-Volt Battery Charger is shown in Fig. 61. When switch S_1 is closed, the full-wave rectified current from the KD2103 bridge circuit charges capacitor C_1 through resistor R_2 and the No. 1488 indicator lamp. When the charge on C_1 is sufficient to activate the diode KD2104, gate current is supplied to the SCR KD2100 and it is triggered into conduction. As a result, the battery is connected to the pulsating dc output of the bridge rectifiers and draws a charging current proportional to the difference in potential between the battery and the rectifier ouput. Resistor R_2 limits the current to a safe

value (to protect the KD2103 rectifiers) in the event that the load is a "dead" battery. The energy in C_1 maintains conduction in the SCR so that charging current continues to flow for practically 180 degrees of each succeeding half-cycle of input until the battery is fully charged. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied through KD2104 as a result of the steady potential on C_1.)

When the battery is fully charged, the two-transistor regenerative switch is triggered into conduction (the triggering point



Basic chassis B (see Fig. 19 for parts list)
C_1 = 50 microfarads, 15 volts, electrolytic
I_1 = pilot lamp, General Electric No.1448 or equivalent
R_1 = potentiometer, 10,000 ohms, 2 watts, linear
R_2 = 5 ohms, 20 watts
R_3 = 150 ohms, ½ watt
R_4 = 470 ohms, ½ watt
R_5 = 1800 ohms, ½ watt
R_6 = 33 ohms, ½ watt

Fig. 61 — Schematic diagram of Single-Kit 12-Volt Battery Charger.

is preset by means of the potentiometer R_1). When the transistors KD2101 and KD2102 become saturated, they provide a discharge path for C_1. The capacitor then discharges through resistor R_6 to about one volt (the drop across the transistors). This value is not sufficient to produce conduction in the diode KD2104, and

therefore the SCR is not triggered on succeeding half-cycles of input. The saturated transistor switch also provides a low-resistance path for the No. 1488 indicator lamp, which glows brightly to signal the fully charged condition of the battery. The current in the lamp circuit (R_2, lamp, and transistor switch) provides a "trickle" charge of approximately 150 milliamperes to the battery.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

Automatic "cut-out" of this circuit is obtained by presetting of the potentiometer R_1. With a fully charged battery (14.3 volts across the terminals) connected across the output of the circuit, R_1 is adjusted so that the indicator lamp just begins to brighten. Special care should be taken to ensure good connections to the battery terminals; poor connections can produce an appreciable voltage drop which will trigger the "cut-out" mechanism before the battery is fully charged.

Circuit No. 9—Single-Kit Battery Charger (3 cell, 6 volts)

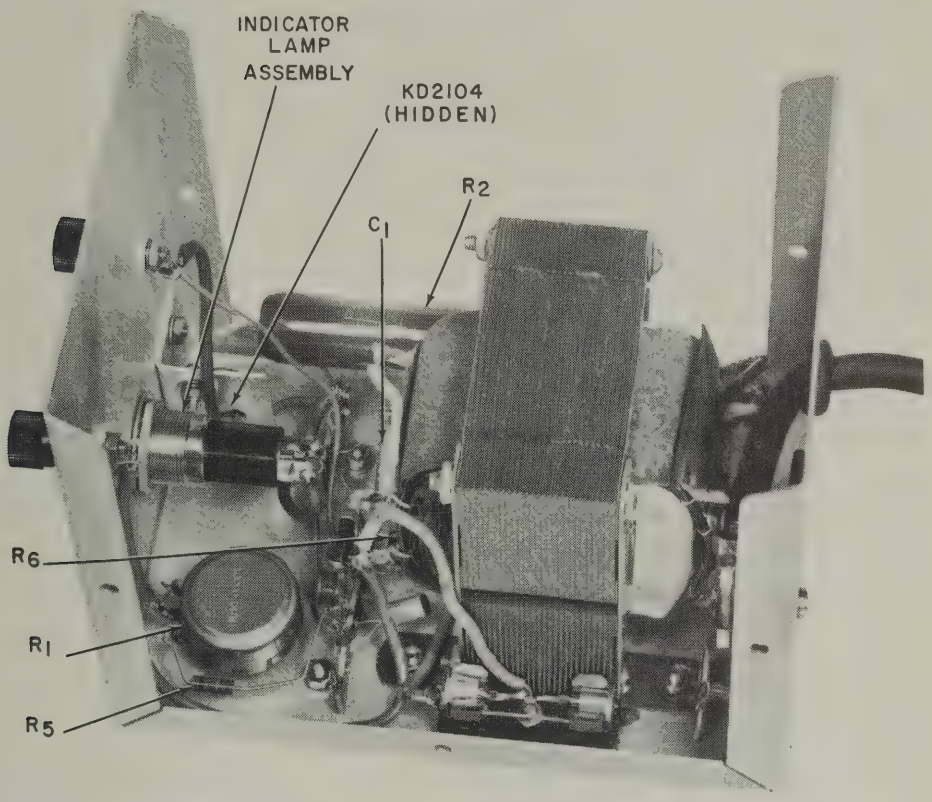


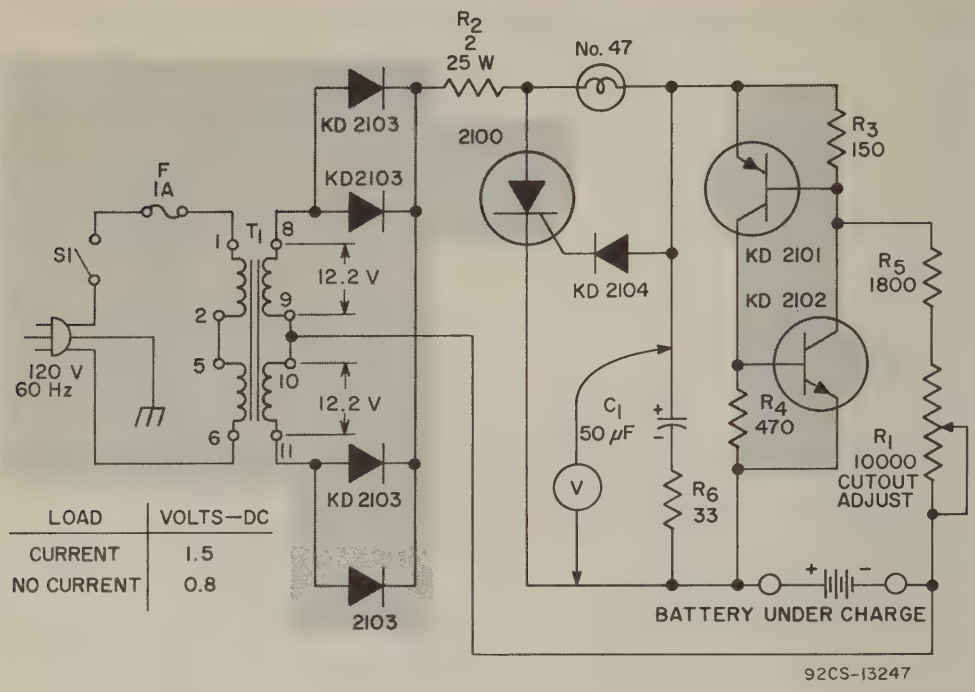
Fig. 62 — Photograph of Single-Kit 6-Volt Battery Charger (call-outs indicate components added to basic chassis).

CONSTRUCTION

The circuit uses the basic chassis B (shown in Fig. 19); four additional resistors, one capacitor, a silicon rectifier KD2104, and an indicator lamp are mounted on the chassis as shown in Fig. 62. The battery is connected as shown in Fig. 63. No additional holes are required in the chassis for this circuit.

CIRCUIT OPERATION

The schematic diagram for the 6-Volt Battery Charger is shown in Fig. 63. This circuit is similar to the battery charger of Circuit No. 8 except for the rectifier configuration. In place of the bridge arrangement used in Circuit No. 8 (and all other circuits in this manual), the silicon rectifiers KD2103 are arranged in a full-wave center-tapped configuration which provides a higher charging current (3.2 amperes as compared to 2 amperes) to the lower-voltage load (6 volts as compared to 12 volts). Except for the rectifier circuit, the value of R_2, and the indicator lamp,



Basic chassis B (see Fig. 19 for parts list)
C_1 = 50 microfarads, 15 volts, electrolytic
I_1 = pilot lamp, General Electric No.47 or equivalent
R_1 = potentiometer, 10,000 ohms, 2 watts, linear
R_2 = 2 ohms, 25 watts
R_3 = 150 ohms, ½ watt
R_4 = 470 ohms, ½ watt
R_5 = 1800 ohms, ½ watt
R_6 = 33 ohms, ½ watt

Fig. 63 — Schematic diagram of Single-Kit 6-Volt Battery Charger.

this circuit is the same as Circuit No. 8 and operates in the same manner.

When switch S_1 is closed, the full-wave rectified current from the KD2103 rectifiers charges capacitor C_1 through resistor R_2 and the No. 47 indicator lamp. When the charge on C_1 is sufficient to activate the diode KD2104, gate current is supplied to the SCR KD2100 and it is triggered into conduction. As a result, the battery is connected to the pulsating dc output of the rectifier circuit and draws a charging current proportional to the difference in potential between the battery and the rectifier output. Resistor R_2 limits the current to a safe value (to protect the KD2103 rectifiers) in the event that the load is a "dead" battery. The energy in C_1 maintains conduction in the SCR so that charging current continues to flow for practically 180 degrees of each

succeeding half-cycle of input until the battery is fully charged. (The SCR is actually cut off near the end of each half-cycle and retriggered shortly after the beginning of each succeeding half-cycle by the current applied through KD2104 as a result of the steady potential on C_1.)

When the battery is fully charged, the two-transistor regenerative switch is triggered into conduction (the triggering point is preset by means of the potentiometer R_1). When the transistors KD2101 and KD2102 become saturated, they provide a discharge path for C_1. The capacitor then discharges through resistor R6 to about one volt (the drop across the transistors). This voltage is not sufficient to produce conduction in the diode KD2104, and therefore the SCR is not triggered on succeeding half-cycles of input. The saturated transistor switch also provides a low-resistance path for the No. 47 indicator lamp, which glows brightly to signal the fully charged condition of the battery. The current in the lamp circuit (R_2, lamp, and transistor switch) provides a "trickle" charge of approximately 150 milliamperes to the battery.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

Automatic "cut-off" of this circuit is obtained by presetting of the potentiometer R_1. With a fully charged battery (7.15 volts across the terminals) connected across the output of the circuit, R_1 is adjusted so that the indicator lamp just begins to brighten. Special care should be taken to insure good connections to the battery terminals; poor connections can produce an appreciable voltage drop which will trigger the "cut-out" mechanism before the battery is fully charged.

Circuit No. 10—Twin-Kit 12-Volt Battery Charger

CONSTRUCTION

The Twin-Kit Battery Charger is built on a special chassis, a 6 x 9 x 5-inch utility box, as shown in Figs. 64 and 65. In addition to the parts listed in Fig. 66, two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits** are required. Resistor R_3 is mounted external to the chassis and is shielded by perforated metal sheeting (preferably aluminum) or by screening material, as shown in Fig. 67, because the heat it generates could affect internal circuit components. When the resistor is mounted on the outside of the chassis and the perforated metal or screening cover is in place, there is no danger to the operator; if this cover is removed, however, care must be taken to make sure that the resistor has cooled enough to permit safe handling.

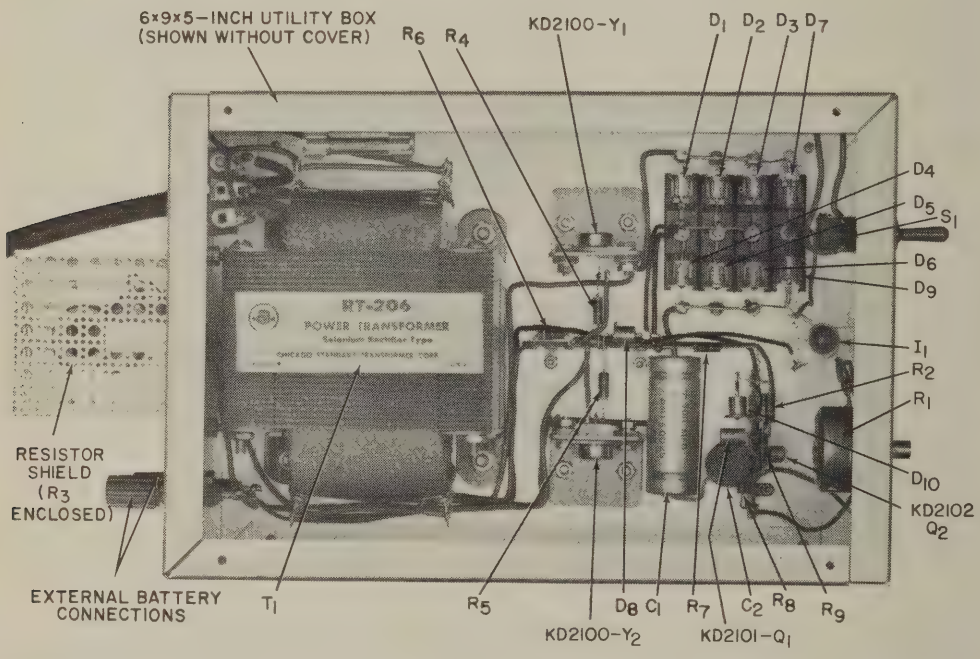


Fig. 64 — Photograph of the Twin-Kit 12-Volt Battery Charger.

CIRCUIT OPERATION

The schematic diagram for this circuit is shown in Fig. 66. Line power is stepped down to approximately 17 volts by transformer T_1. The output of the transformer is full-wave rectified by the two KD2103 diode groups and the two KD2100 SCR's. The KD2103 diodes are grouped to permit the circuit to operate at the 5-ampere current rating.

The SCR's are triggered early in each cycle through the D_{10}, I_1 (the lamp), D_9, R_4 combination or the D_{11}, I_1, D_9, R_5 combination, depending on which half of the input cycle is being conducted by the transformer secondary. The current conducted by the SCR's is used to charge the battery to a predeter-

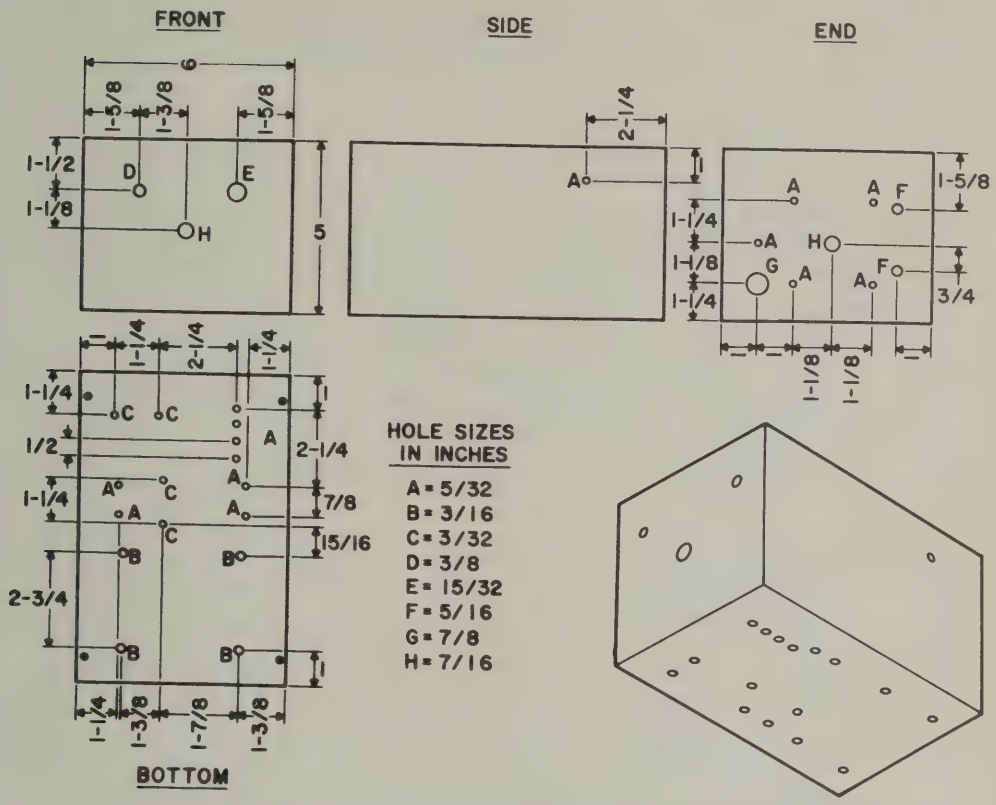


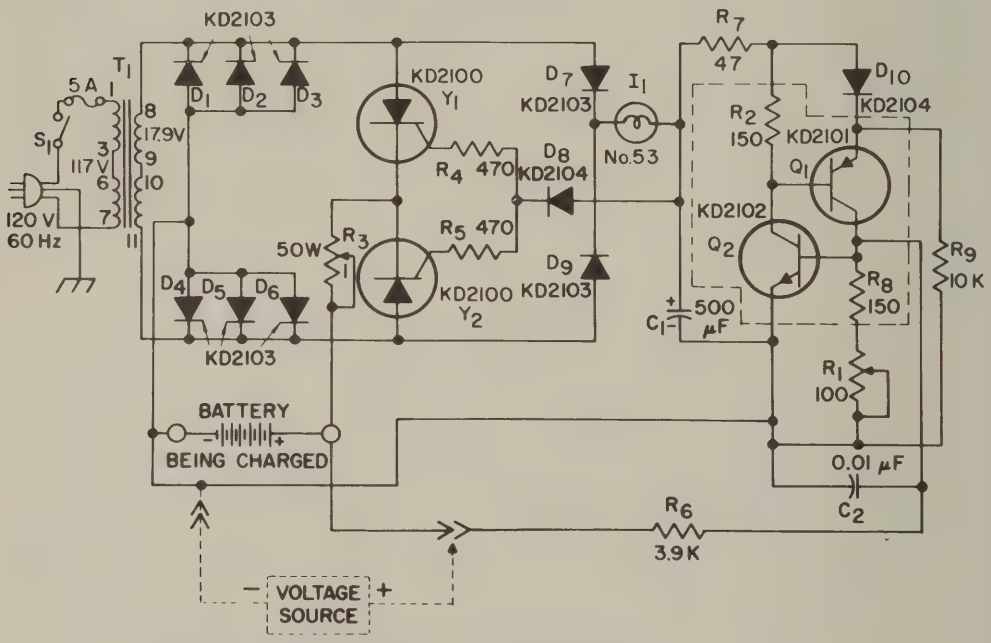
Fig. 65 — Drilling details for Twin-Kit Battery Charger.

mined level. When this level is reached, the regenerative switch starts to conduct and turns on the lamp.

When the regenerative switch conducts through the lamp, the gates of the SCR's are bypassed and thus the charging current is terminated. Resistor R_6 is the voltage-sensing resistor for the regenerative switch; potentiometer R_1 sets the triggering level of the switch. The switch is set to trigger at a desired level by temporarily removing R_6 from the positive battery terminal and connecting it to a voltage source, as shown in Fig. 66. The voltage source can be a low-current power supply or battery; it should be set to 14 volts. With the source connected, the potentiometer is set so that the regenerative switch just triggers (so that the lamp just lights). After the voltage source is removed, the regenerative switch can be reset by momentarily operating the power switch. When power to the charger is interrupted, the regenerative switch

is reset. Once the calibration has been made, the potentiometer setting need not and should not be changed. A potentiometer that has characteristics similar to those designated for R_1 in the parts list but that has a slotted screw-driven shaft and a locking bushing is helpful in maintaining the setting.

The externally mounted resistor, R_3, must be adjusted to slightly less than one ohm so that the current will be limited to 5 amperes or less.



Chassis, 5x6x9-inch utility box with cover
Perforated metal sheet or screening, 8 x 6 inches
Binding posts, E.F. Johnson No.111-101
or equivalent; 2 required
Fuse, 5 amperes, type 3AG
Fuse Holder, 3AG Littelfuse or equivalent;
5 required
Lamp socket, Dialco No.710 or equivalent
Power cord, 3 wire, No.18 AWG
Strain relief, Heyco 7P or equivalent
Terminal strip, H.H. Smith No.864 or equivalent
Terminal strip, miniature, H.H. Smith No.1070
or equivalent
C_1 = 500 microfarads, 25 volts, electrolytic
C_2 = 0.01 microfarad, 1000 volts, disc-ceramic
I_1 = Lamp, indicator, General Electric No.53
or equivalent
R_1 = potentiometer, 100 ohms, 2 watts, linear
R_2, R_8 = 150 ohms, ½ watt
R_3 = 1 ohm, 50 watts, adjustable
R_4, R_5 = 470 ohms, ½ watt
R_6 = 4700 ohms, ½ watt
R_7 = 47 ohms, ½ watt
R_9 = 10,000 ohms, ½ watt
S_1 = SPST, toggle, 3 amperes, 125 volts
T_1 = transformer, Stancor RT-206 or equivalent
Hardware: 2-56 and 6-32 screws, nuts, and lockwashers

Fig. 66 — Schematic diagram of Twin-Kit Battery Charger.

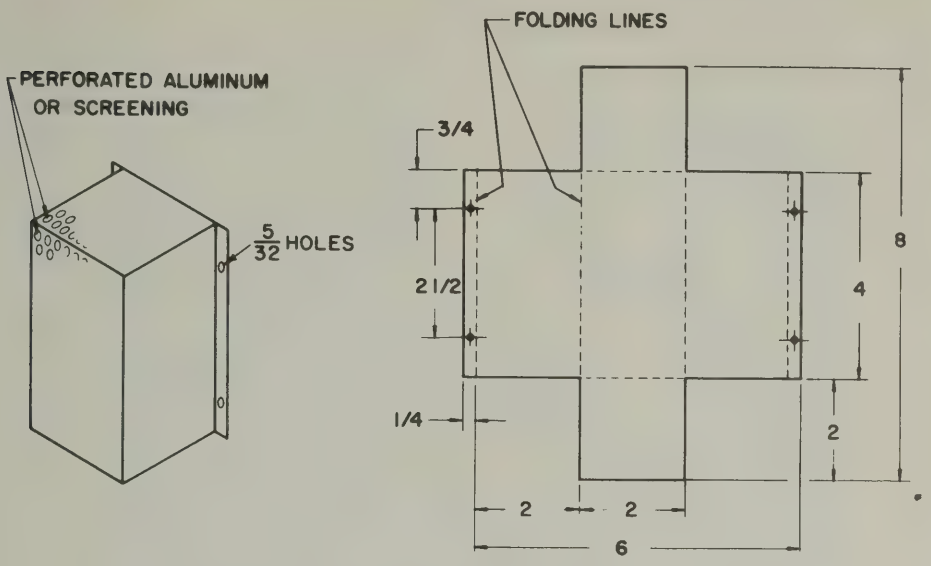


Fig. 67 — Details of resistor shield.

Circuit No. 11
Model Train and Race-Car Speed Control

The Model Train and Race-Car Speed Control circuit can be used to control "hobby-type" vehicles.

This circuit can be used to provide continuous and smooth control of the speed of model vehicles which are designed to operate at dc voltages up to 12 volts. Model speed can be adjusted over the complete range from zero to full speed. This control circuit is useful for starting, stopping, and adjusting the speed of most model railroad trains, race cars, and similar "hobby"-type vehicles.*

CONSTRUCTION

The circuit uses the basic chassis B (shown in Fig. 19); nine additional resistors, two capacitors, and a silicon rectifier KD2104 are mounted on the chassis as shown in Fig. 68. The output leads are connected either to a reversing switch or to the slot track of the model vehicle. No additional holes are required in the chassis for this circuit.

CIRCUIT OPERATION

The schematic diagram for this Model Train and Race-Car Speed Control is shown in Fig. 69. The operating speed of the model railroad train or race car with which this circuit is used is determined by the delay involved in triggering the SCR KD2100

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

into conduction after the start of each half-cycle of ac input voltage. This delay time, in turn, is controlled by adjustment of the potentiometer R_1. Because the load and the SCR are in parallel (rather than in series as in the Single-Kit Universal Motor Speed Control, Circuit No. 3), output voltage is available at the load only when the SCR is not conducting. When the control knob is set to its maximum clockwise position, therefore, maximum delay in triggering the SCR is obtained and maximum speed is attained in the model vehicle.

When switch S_1 is closed, the pulsating direct current from the bridge rectifiers KD2103 charges capacitor C_2 through the resistor R_2 and the diode KD2104, and a voltage appears across the output terminals. Under conditions of minimum conduction of the SCR (approximately 100 degrees of each input half cycle of voltage), a maximum voltage of approximately 13 volts is present at the output terminals. As the control knob is turned

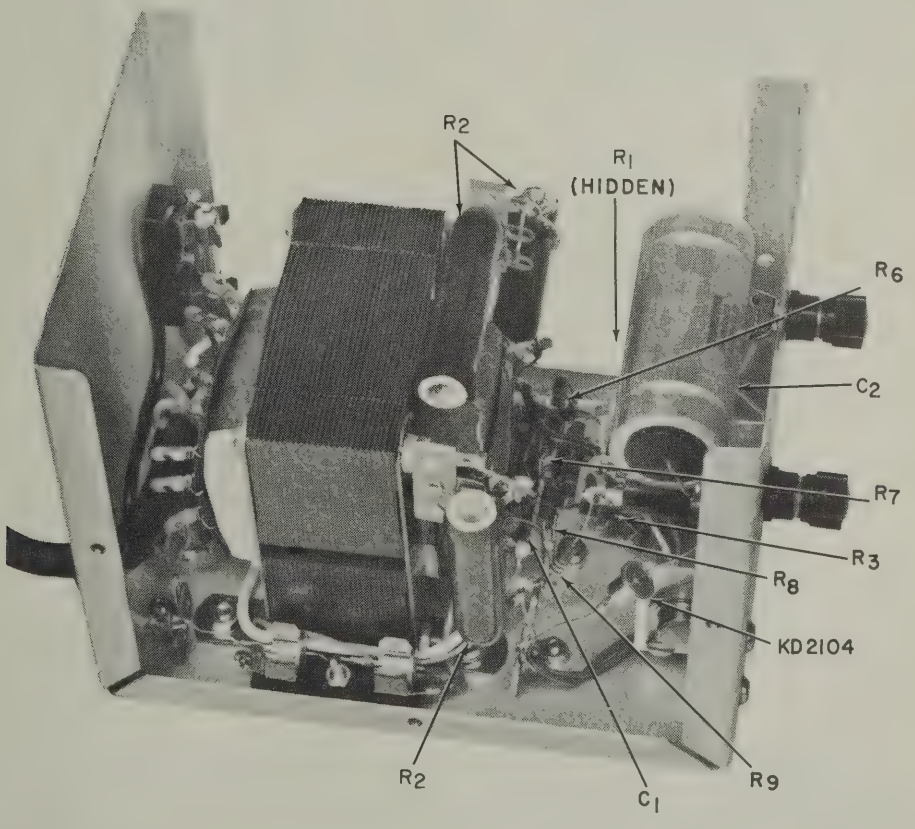
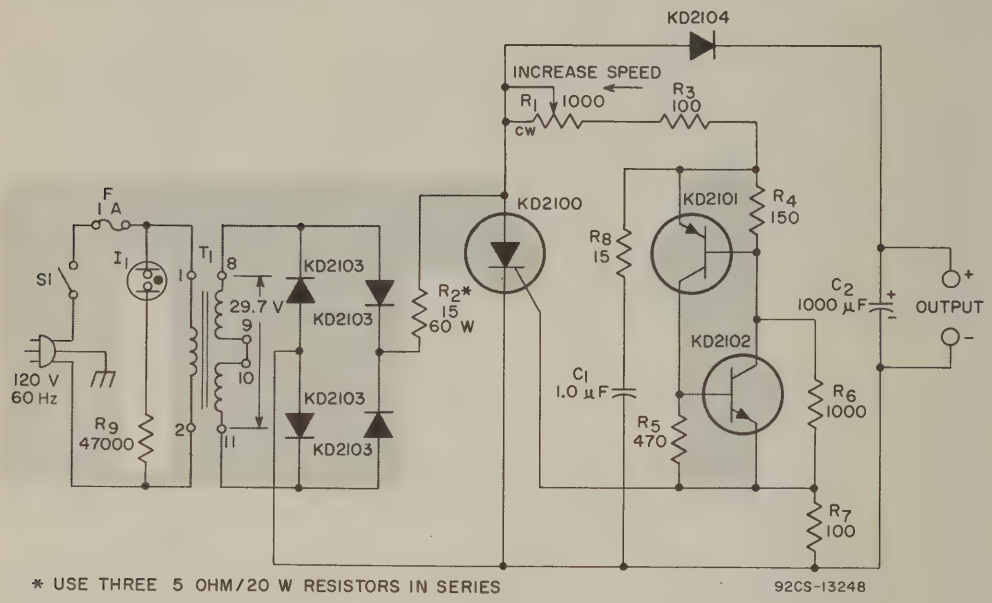


Fig. 68 — Photograph of Model Train and Race-Car Speed Control (call-outs indicate components added to basic chassis).

in a counterclockwise direction, the resistance of R_1 is decreased and the current through R_1, R_3, and R_8 charges capacitor C_1 more quickly to the triggering potential of the two-transistor regenerative switch. The switch, in turn, triggers the SCR into conduction, and the voltage across the output terminals drops to slightly less than one volt when the control knob is in the most counterclockwise position.



Basic chassis B (see Fig.19 for parts list).
Terminal Strip, Cinch-Jones No.52A or equivalent;
2 required; ream to clear 8-32 bolts on transformer
C_1 = 1 microfarad, 200 volts, paper
C_2 = 1000 microfarad, 25 volts, electrolytic
I_1 = lamp, neon, General Electric NE-83, NE-2 or equivalent
R_1 = potentiometer, 1000 ohms, 2 watts, linear
R_2 = 5 ohms, 20 watts; 3 required
R_3, R_7 = 100 ohms, ½ watt
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 1000 ohms, ½ watt
R_8 = 15 ohms, ½ watt
R_9 = 47,000 ohms, ½ watt

Fig. 69 — Schematic diagram of Model Train and Race-Car Speed Control.

Because the capacitor C_2 performs an integrating function, the output voltage approaches a steady dc level determined by the relative duration of the "on" and "off" periods of the SCR. The silicon rectifier KD2104 isolates the anode of the SCR from the potential on C_2 so that the capacitor cannot discharge through the SCR when it is triggered into conduction and so that the

anode voltage falls to zero and turns off the SCR at the end of each input half-cycle. Resistor R_7 helps to stabilize operation of the SCR, and also provides a parallel path for discharge of C_1 after the SCR is triggered into conduction. Resistor R_2 limits the current through the bridge rectifier circuit to the maximum allowable value of two amperes in the event of a short circuit across the output terminals.

The parallel arrangement of the load and the SCR in this circuit provides superior control and speed regulation at the operating voltages of model vehicles. The circuit is inherently self-regulating, i.e., it maintains essentially constant speed under varying load conditions. When the mechanical load increases (e.g., when the vehicle travels on an inclined portion of track), the vehicle motor tends to slow down. The motor current then increases, and the voltage across the capacitor C_2 decreases. However, because this voltage is also the potential for the timing circuit (R_1, R_3, R_8, and C_1), the capacitor C_1 charges more slowly and the delay in triggering the SCR is increased. As a result, the output voltage is also increased and the speed is maintained essentially constant.

Fig. 70 shows the waveshapes across the SCR (from anode to cathode) for one cycle of input voltage at (a) full speed,

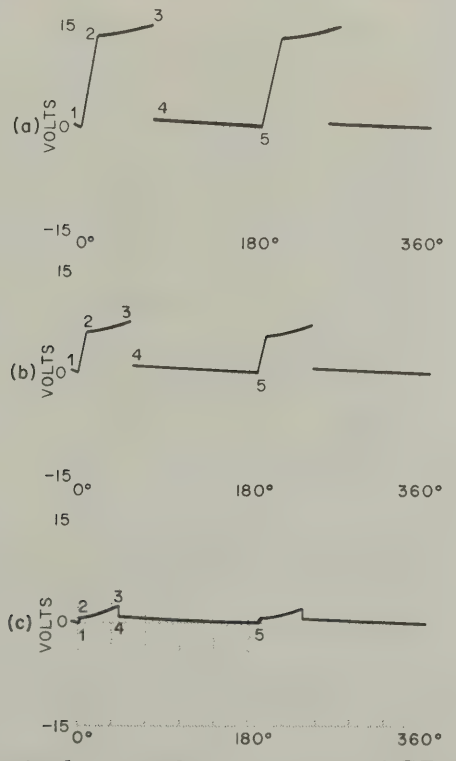
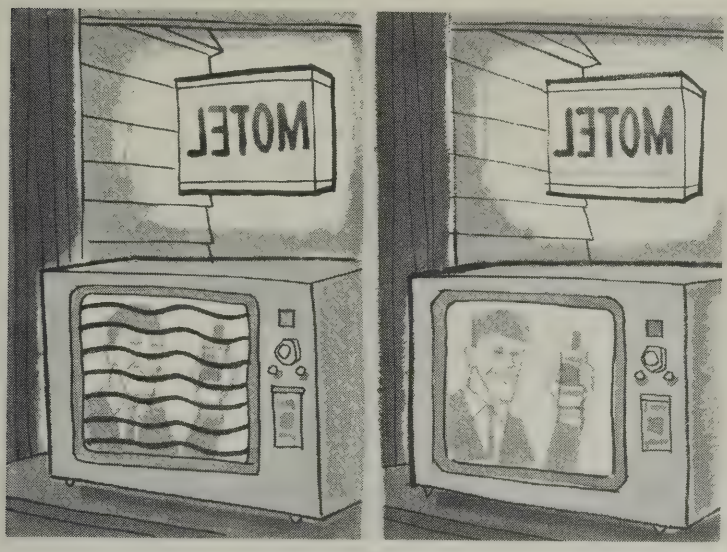


Fig. 70 — Typical waveshapes across SCR in Model Train and Race-Car Speed Control at (a) full speed. (b) half speed, and (c) zero speed.

(b) half speed, and (c) zero speed. At the start of each half-cycle (point 1), the SCR is off. The anode voltage then follows the increasing sine wave until it equals the voltage on capacitor C_2 (point 2). The diode KD2104 then starts to conduct, and C_2 charges until the SCR is triggered into conduction (point 3) by the timing portion of the circuit. At the start of conduction, the anode drops to 0.6 volt (point 4), the diode KD2104 stops conducting, and capacitor C_2 discharges into the load until point 2 of the next half-cycle.

The SCR stops conducting when the input voltage drops to zero at the end of the half-cycle (point 5). The load-voltage waveshape is described by the charge and discharge paths of capacitor C_2.

ELECTRONIC SYNCHRONOUS SWITCHES



Flashing signs switched by a radio-frequency-interference-free Electronic Synchronous Switch do not affect TV reception.

Synchronous switches are useful when it is desirable to switch a load without generating radio-frequency interference or transients. Examples of such cases are flashing signs or lights and electrically operated doors, i.e., any repetitive operation in which radio-frequency interference caused by switching is a concern. The synchronous switch eliminates sparking at relay contacts but can not eliminate the sparking at the brushes in a power tool; it only prevents switching noise. (Radio-frequency noise not controllable through the use of a synchronous switch can be alleviated by use of the filter shown in Fig. 44.) Radio-frequency interference caused when the current to the load increases or decreases very rapidly (e.g., when the current is being switched) can be prevented by eliminating the rapid current change. Rapid changes in current can be eliminated by switching the power to the load when the voltage is in the zero portion of the ac wave.

Application of power to ac loads that have a total power rating up to 240 watts can be interrupted by the Single-Kit Elec-

tronic Synchronous Switch when the instantaneous voltage across the load is sufficient to cause switching transients that might damage the equipment or produce radio-frequency interference. Any of the three Twin-Kit Electronic Synchronous Switches can be used as a radio-frequency-interference-free switch for loads up to one kilowatt. One Twin-Kit Switch must be operated manually; a small negative signal turns the other Twin-Kit Switch on or off automatically.*

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 12
Single-Kit Electronic Synchronous Switch

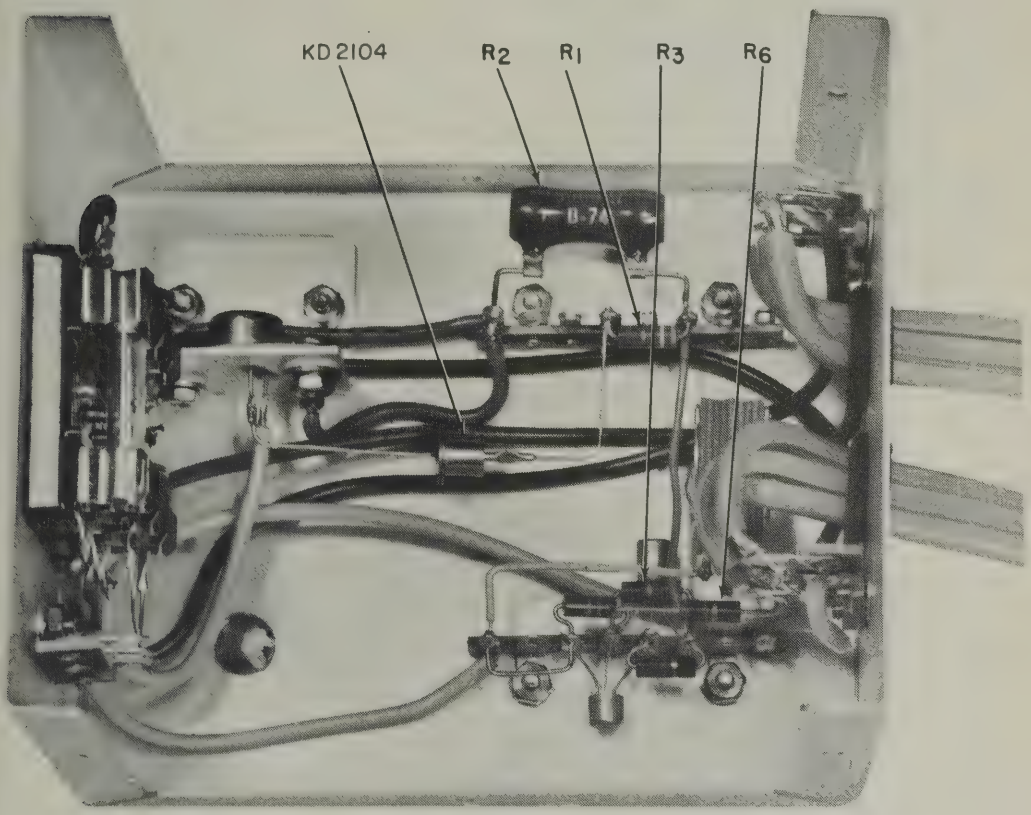


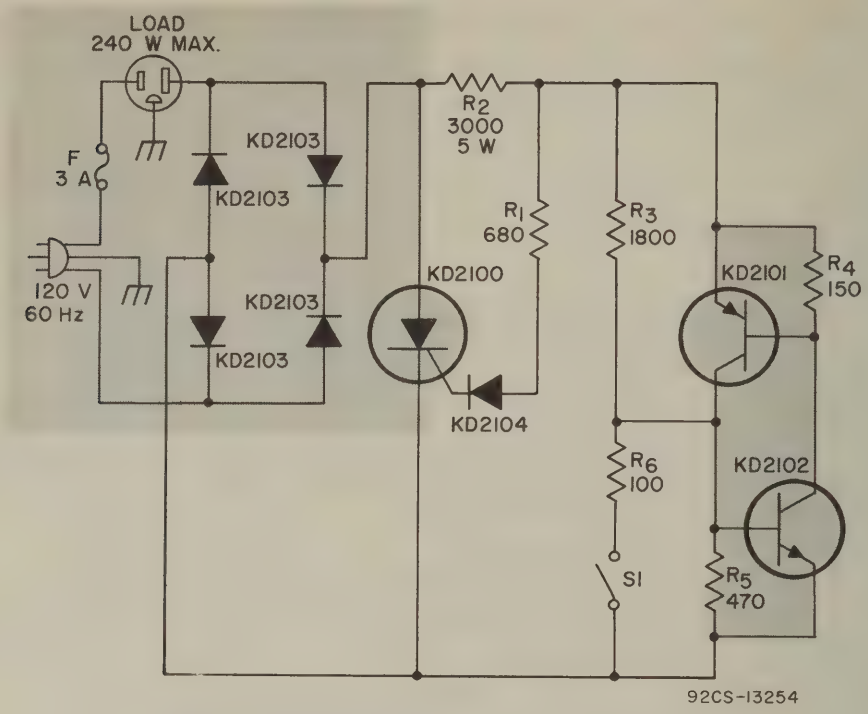
Fig. 71 — Photograph of Single-Kit Electronic Synchronous Switch (call-outs indicate components added to basic chassis).

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18); four additional resistors and a silicon rectifier KD2104 are mounted on the chassis as shown in Fig. 71. No additional holes are required in the chassis for this circuit, and no potentiometer is used.

CIRCUIT OPERATION

The schematic diagram for this Electronic Synchronous Switch is shown in Fig. 72. This circuit acts to prevent application of power to the load during periods when the supply voltage has a high instantaneous value. When the input plug is inserted in a 120-volt receptacle (with the load connected to the output plug), source power is applied through the bridge rectifiers



Basic chassis A (see Fig.17 for parts list)
R_1 = 680 ohms, ½ watt
R_2 = 3000 ohms, 5 watts
R_3 = 1800 ohms, ½ watt
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 100 ohms, ½ watt

Fig. 72 — Schematic diagram of Single-Kit Electronic Synchronous Switch.

KD2103 to two parallel circuits; one consisting of resistors R_2 and R_1, the silicon diode KD2104, and the gate-cathode junction of the SCR KD2100; the other consisting of the two-transistor regenerative switch, resistors R_3 and R_6, and the switch S_1. The circuit is designed so that triggering of the SCR occurs when the instantaneous supply voltage is 6.5 volts, and the transistor switch is triggered when the instantaneous supply voltage is 2.8 with S_1 open and 13.5 volts with S_1 closed. When S_1 is open, therefore, the transistor switch is always triggered before the SCR. Because current is then shunted through the regenerative switch for the remainder of each input half-cycle, the SCR can not be triggered into conduction, and only minute power is applied to the load.

When switch S_1 is closed, resistor R_6 is connected in parallel with R_5 so that a voltage of 13.5 volts is required to trigger the transistor switch. If the supply voltage is 13.5 volts or more at the instant the switch is closed, the transistor switch remains

in conduction, the SCR is not triggered, and no current flows through the load for the remainder of the input half-cycle. If the supply voltage is less than 13.5 volts, however, the transistor switch stops conducting, and the SCR is triggered (immediately if the voltage is 6.5 volts or more; otherwise, when it reaches 6.5 volts). Power is then safely applied to the load, and load current continues to flow for the remainder of the half-cycle.

At the start of each succeeding half-cycle of input voltage, current flows through resistors R_2 and R_1 and diode KD2104 to the gate of the SCR KD2100, and the SCR is triggered when the input voltage reaches 6.5 volts. Load current then continues to flow during succeeding input half-cycles until the switch S_1 is opened.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

Because the load is connected on the line side of the bridge rectifier, this circuit can be used to protect any ac load having a power rating up to 240 watts. In addition, because the current flow through the switch S_1 is as small as two or three milliamperes, a remote switch having a low current rating can be used if desired.

Circuit No. 13
Twin-Kit Electronic Synchronous Switch (manually operated)

CONSTRUCTION

The circuit uses the basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Four additional resistors, two capacitors, two binding posts, and an SPST (single-pole, single-throw) switch are mounted on the chassis as shown in Fig. 73.

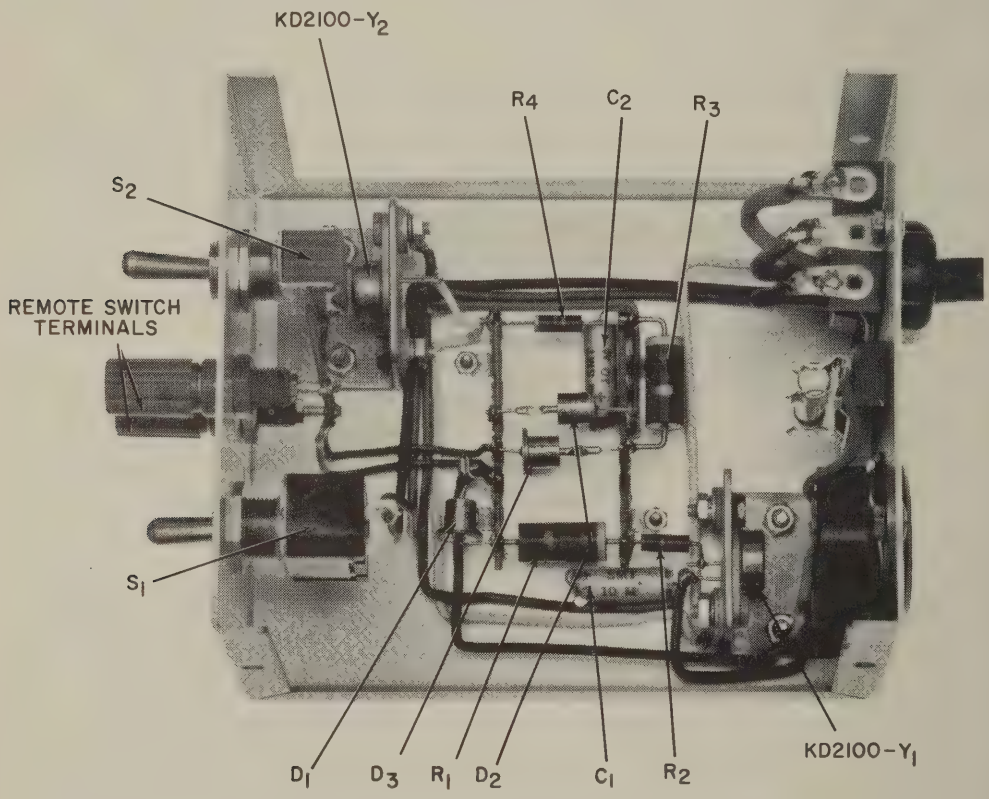
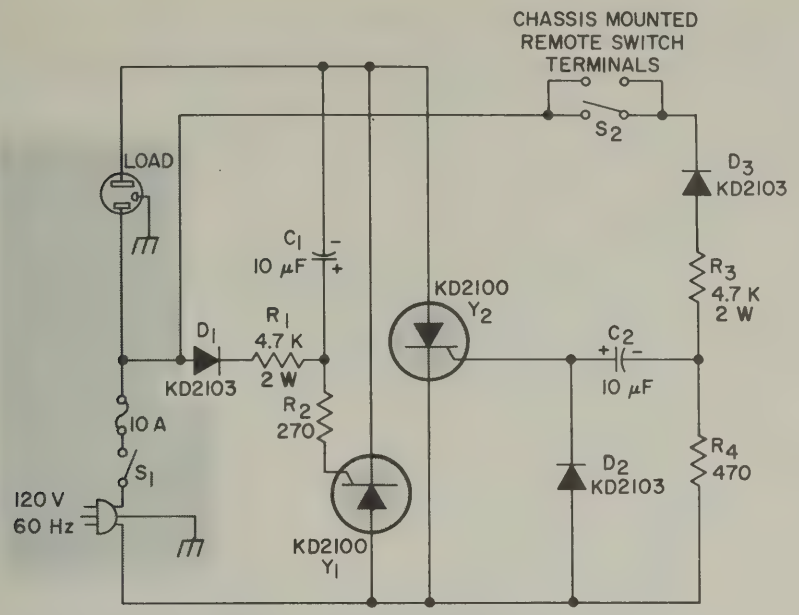


Fig. 73 — Photograph of Manual Twin-Kit Electronic Synchronous Switch (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for the Manual Twin-Kit Switch is shown in Fig. 74. This switch can be used to switch loads up to one kilowatt by use of a chassis-mounted switch or a remotely mounted low-current switch connected to chassis-mounted terminals.



Basic chassis C (see Fig.20 for parts list)
Binding posts, E.F. Johnson No.111-101
or equivalent; 2 required
C_1, C_2 = 10 microfarads, 15 volts, electrolytic
R_1, R_3 = 4700 ohms, 2 watts
R_2 = 270 ohms, ½ watt
R_4 = 470 ohms, ½ watt
S_2 = Switch, SPST, toggle, 3 amperes, 125 volts

Fig. 74 — Schematic diagram of Manual Twin-Kit Electronic Synchronous Switch.

When the remotely mounted or chassis-mounted switch S_2 is closed, the KD2103 diodes D_2 and D_3 conduct when they are forward-biased by the power source. The conducted current charges C_2. This charge is applied to the gate of the SCR Y_2 during the next half-cycle and turns it on. A voltage is then applied to the load and the network consisting of D_1, R_1, and C_1; this voltage causes C_1 to charge. On the following half-cycle, the residual charge on C_1 is applied to the gate of Y_1 and turns it on. This process repeats as long as S_2 or the remote switch is closed.

When S_2 is opened, the C_2 charging path is interrupted. Because C_2 cannot charge, there is no signal applied to the gate of Y_2; therefore, Y_2 does not conduct and power is removed from the load for this half-cycle. Because there is no power across the load and the network across it, C_1 cannot charge. As a result, power is removed from the load during the next half-cycle. Thus, the load circuit is effectively opened. SCR's Y_1 and Y_2 remain nonconducting as long as S_2 remains open.

Circuit No. 14
Twin-Kit Electronic Synchronous Switch
(automatically operated)

CONSTRUCTION

The circuit uses the basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Five additional resistors, two capacitors, and two binding posts are mounted on the chassis as shown in Fig. 75.

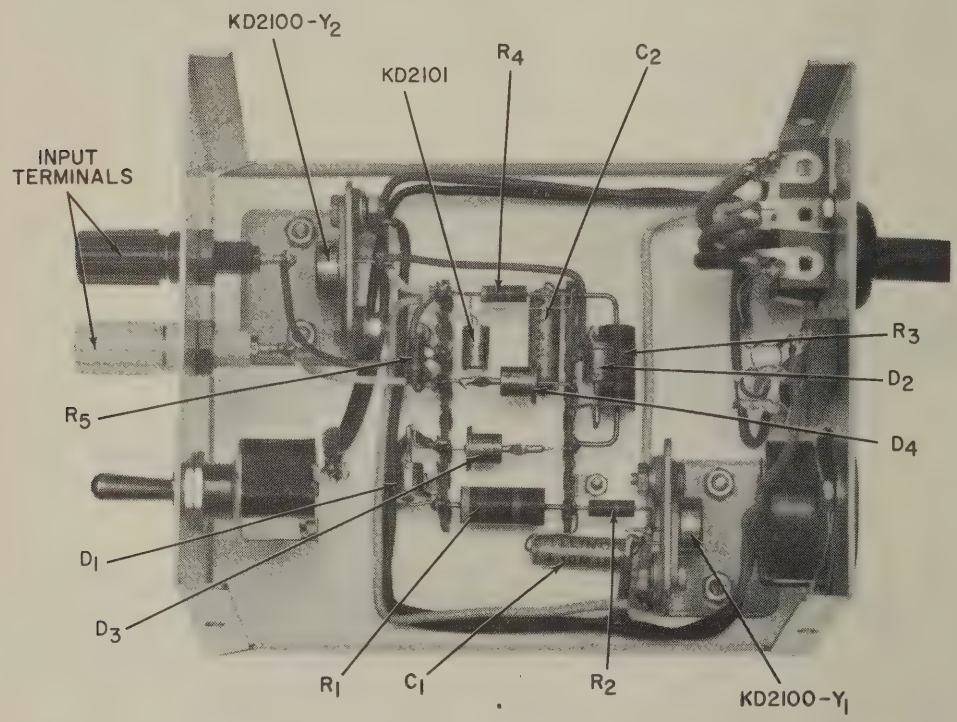
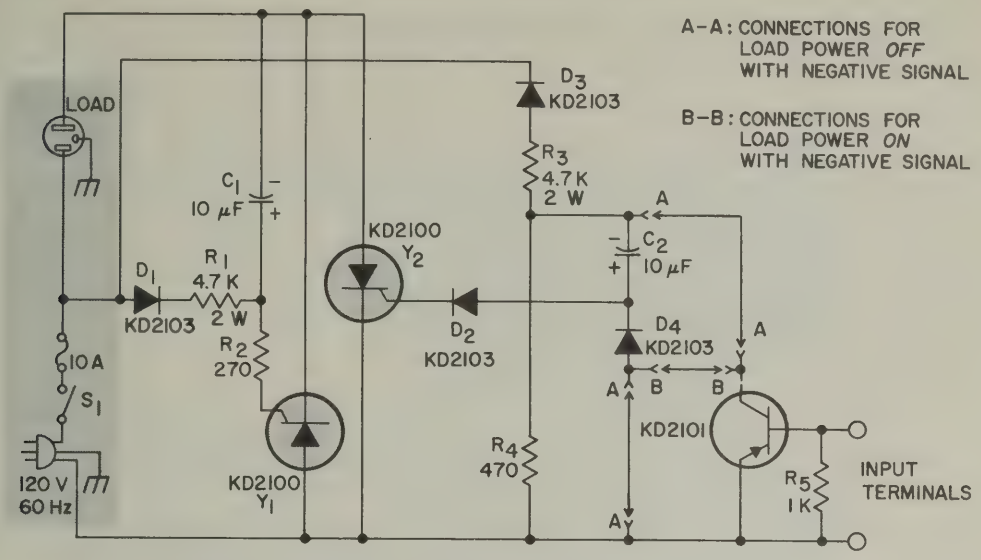


Fig. 75 — Photograph of Automatic Twin-Kit Electronic Synchronous Switch (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for the Automatic Twin-Kit Switch is shown in Fig. 76. The diagram illustrates wiring for two modes; depending upon the connections made to the collector of the KD2101 transistor, a negative signal switches load power on or off.

When the KD2101 transistor is connected as shown by the B-B lines in Fig. 76, application of a negative signal turns the load power on. When an input signal is applied, transistor



Basic chassis C (see Fig.20 for parts list)
Binding posts, E.F. Johnson No.111-101
or equivalent; 2 required
C_1, C_2 = 10 microfarads, 15 volts, electrolytic
R_1, R_3 = 4700 ohms, 2 watts
R_2 = 270 ohms, ½ watt
R_4 = 470 ohms, ½ watt
R_5 = 1000 ohms, ½ watt

Fig. 76 — Schematic diagram for Automatic Twin-Kit Electronic Synchronous Switch.

KD2101 conducts, provided that the emitter has been made positive by the power source, and charges capacitor C_2 through D_4 and R_3. On the following half-cycle, the charge on C_2 is applied to the gate of the SCR Y_2, turning it on and placing a voltage across the load. The load voltage also appears across the combination of D_1, R_1, and C_1, causing the capacitor to charge. The charge on C_1 turns on Y_1 during the next half-cycle. This process repeats as long as there is a negative signal at the input terminals.

When the signal is removed, the KD2101 transistor becomes nonconductive, and thus opens the charging path for capacitor C_2. If C_2 is not charged, it cannot turn on Y_2; therefore, no voltage is applied across the load. Because there is no voltage across the load capacitor, C_1 cannot charge and turn on Y_1. At this time the circuit to the load is open; both SCR's remain off until another signal of sufficient magnitude is impressed on the input terminals.

When the KD2101 is connected as shown by the A-A lines, a negative signal turns the load power off. When no input signal is applied to transistor KD2101, the transistor does not

conduct. Capacitor C_2 can then charge through resistor R_3 and diodes D_3 and D_4 when the diodes are forward-biased from the power source. On the following half-cycle, the charge on C_2 is applied to the gate of Y_2 and turns it on. The load then receives its first half-cycle of power. The voltage across the load is also applied to the combination of D_1, R_1, and C_1, causing the capacitor to charge. The charge on C_1 turns on Y_1 during the next half-cycle. This process repeats as long as there is no signal on the KD2101 transistor.

When a negative signal is applied at the input terminals, transistor KD2101 turns on and bypasses the charging path to C_2. If this capacitor cannot charge, Y_2 cannot be turned on. Therefore, the circuit to the load is opened for the first half-cycle. Because there is no voltage across the load for this half-cycle, capactior C_1 cannot charge and turn on Y_1 during the next half-cycle. Both SCR's, therefore, remain off as long as a negative signal is applied at the input. For greater reliability, a base current of 1 to 2 milliamperes should be provided in the input.

LIGHT-OPERATED SWITCHES

An application of a Light-Operated Switch is to turn on dock lights from a boat with a minimum of equipment and at a distance from the dock.

Single-Kit Light-Operated Switches are useful for switching ac/dc loads such as incandescent lamps, heaters, or universal motors when the ambient light level rises above or falls below a minimum pre-set level. A Twin-Kit Circuit may be used with similar ac-only loads. The circuits are very sensitive and can be adjusted for illumination levels ranging from normal ambient light to the brightness of any artificial light source. All circuits can be locked in the switched mode through the use of the "latching circuit".

Possible applications include the activation of warning or advertising signs at night by the headlights of approaching vehicles, measuring the relative whiteness or reflectivity of various surfaces, and switching lights in remote or unattended locations at daybreak or nightfall (street and parking-lot lights). A light-operated switch may also be used by boat owners to turn on dock lights when returning for the night. If the light sensor is mounted at the end of a long tube, the switch is activated only when the boat

owner shines a light down the tube. This application for the switch is particularly useful.

Three light-operated switches are shown. One Single-Kit Switch turns on the load with an increase in light; a second Single-Kit Switch turns off the load under similar conditions. Both of these switches can handle loads that have ratings up to 240 watts. The Twin-Kit Switch is capable of switching loads up to one kilowatt, and can be wired to switch the load on or off with an increase in light level.*

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 15—Single-Kit Light-Operated Switch (turns on with increase in light)

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18) in conjunction with the photocell contained in the **RCA Add-On Light-Sensor Experimenter's Kit KD2106.** (The photocell and a suggested mounting arrangement are shown in Fig. 39.) Four additional resistors, one capacitor, and an Amphenol microphone connector (for the photocell) are mounted on the chassis as shown in Fig. 77. An additional hole is drilled in the chassis for mounting of the microphone connector.

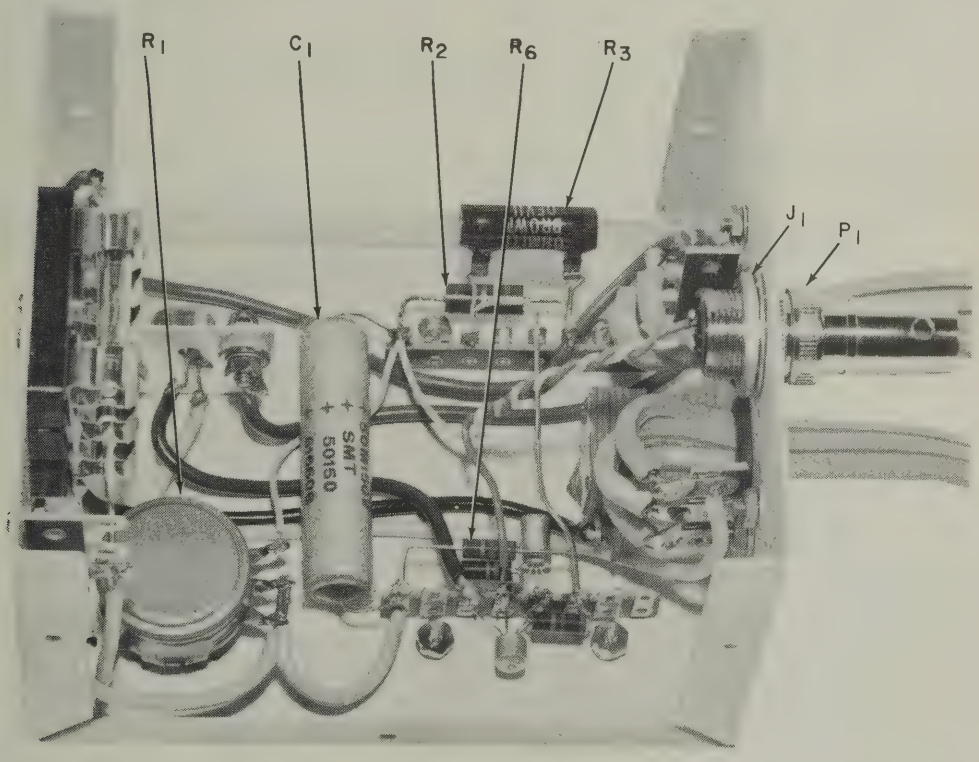
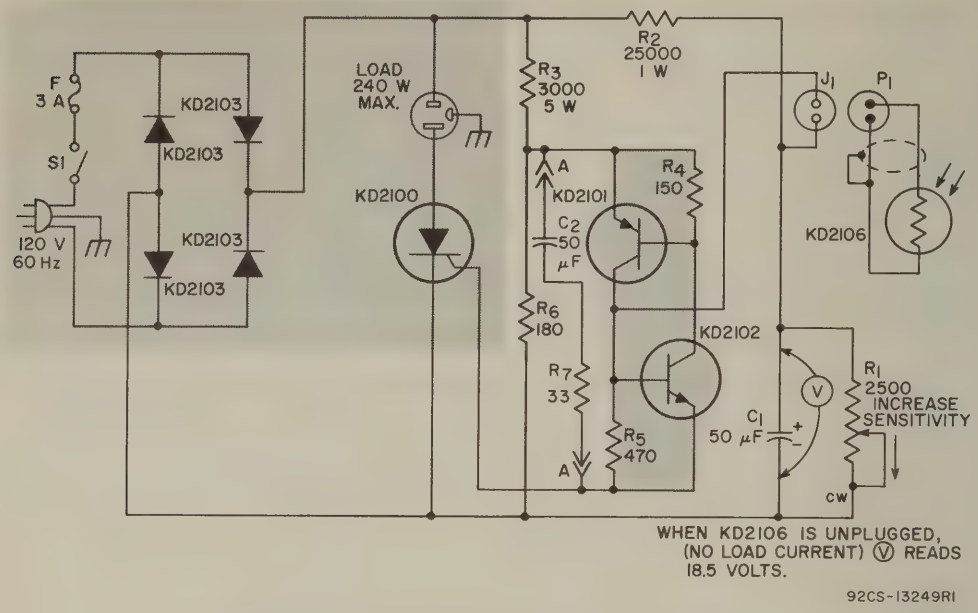


Fig. 77 — Photograph of Single-Kit Light-Operated Switch that turns on with increase in light (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Light-Operated Switch is shown in Fig. 78. The light level at which this circuit applies power to the load is adjusted by means of the sensitivity control R_1. When the switch S_1 is closed, rectified current from the



Basic chassis A (see Fig.17 for parts list)
Connector, auto radio antenna, H.H. Smith
No.1300 or equivalent
Kit, KD2106
Wire for photocell, any two-wire cord (lamp cord);
in exceptionally long runs use shielded cable.
C_1 = 50 microfarads, 150 volts, electrolytic
C_2* = 50 microfarads, 15 volts, electrolytic
J_1 = chassis connector, female, Amphenol 80-2 or equivalent
P_1 = cable connector, male, Amphenol 80-2 or equivalent
R_1 = potentiometer, 2500 ohms, 2 watts, linear
R_2 = 25,000 ohms, 1 watt
R_3 = 3000 ohms, 5 watts
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 180 ohms, ½ watt
R_7* = 33 ohms, ½ watt
* Optional latching circuit parts.

Fig. 78 — Schematic diagram of Single-Kit Light-Operated Switch that turns on with increase in light.

bridge rectifiers KD2103 charges C_1 to a potential that is determined by the setting of potentiometer R_1. Resistors R_1 and R_2 and capacitor C_1 function as a power source for photocell KD2106. Potentiometer R_1 is set so that at ambient light levels the potential on capacitor C_1 is insufficient to trigger the two-transistor regenerative switch.

As the incident light level on KD2106 increases, however, the resistance of the photocell decreases and the increased current through it, resistor R_5, and the gate-cathode path of the SCR then triggers the transistor switch. When the switch becomes

saturated, the current through R_3 is applied to the gate of the SCR KD2100 and triggers it into conduction to complete the load circuit. Resistors R_3 and R_6 form a voltage divider that keeps the potential across the transistor switch within design limits when the switch is not conducting. As long as the illumination remains above the required level, the transistor switch is re-triggered early in each half cycle of ac input by means of the current supplied from capacitor C_1, and the SCR is, in turn, re-triggered.

When the light level decreases below the minimum required level, the resistance of KD2106 increases, the current from capacitor C_1 drops below the value required to trigger the transistor switch, and the SCR is not triggered at the beginning of succeeding input half-cycles until the next increase in illumination. In addition to its function as part of the voltage divider for the regenerative switch, resistor R_3 also functions as a load resistor for the SCR gate circuit.

If it is desired to lock the switch into the switched mode (i.e., to keep the load on), the wiring designated A in Fig. 78 should be used. Wiring A comprises the "latching circuit".

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The sensitivity of the circuit is adjusted prior to use by means of the potentiometer R_1. For maximum sensitivity, the control knob is turned in a clockwise direction until the load conducts current, and is then turned counterclockwise until the load just stops conducting. Further rotation in the counterclockwise direction reduces the sensitivity, i.e., capacitor C_1 charges to a lower potential and a greater amount of light is required to reduce the resistance of KD2106 enough to allow sufficient current through R_5 to trigger the transistor switch.

Because the power supplied to the load is rectified ac, this circuit should be used only with ac/dc loads such as incandescent lamps, heaters, and small universal motors.

Circuit No. 16—Single-Kit Light-Operated Switch (turns off with increase in light)

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18) in conjunction with the photocell contained in the **RCA Add-On Light-Sensor Experimenter's Kit KD2106.** (The photocell and a suggested mounting arrangement are shown in Fig. 39.) Three additional resistors, one capacitor, a silicon rectifier KD2104, and an Amphenol microphone connector (for the photocell) are mounted on the chassis as shown in Fig. 79. An additional hole is drilled in the chassis for mounting of the microphone connector.

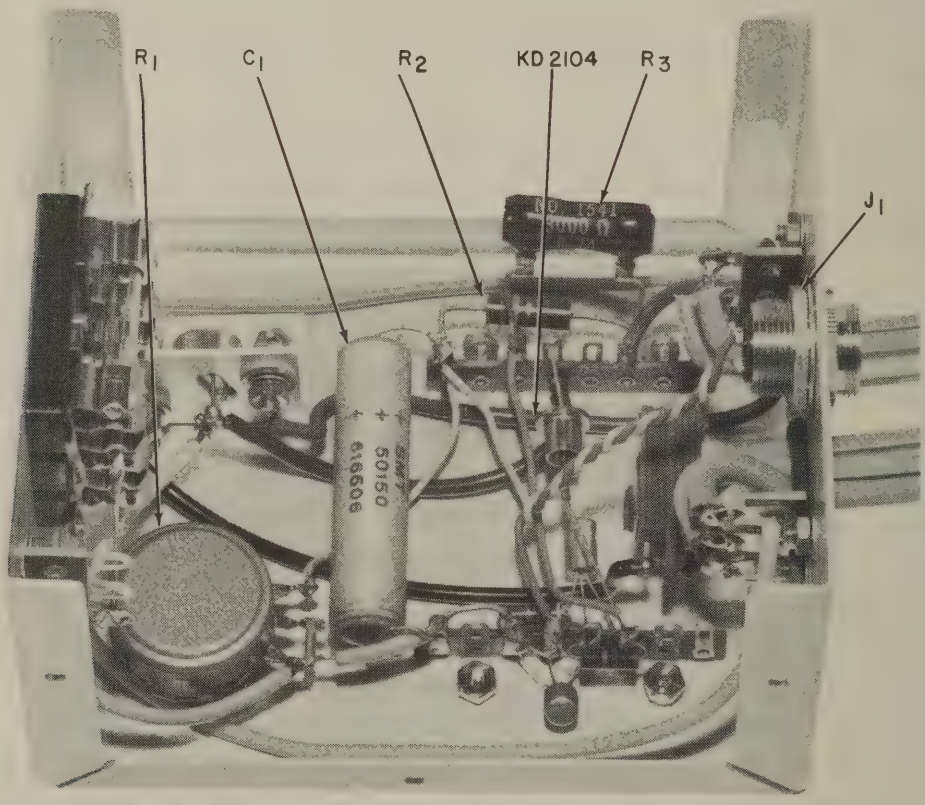
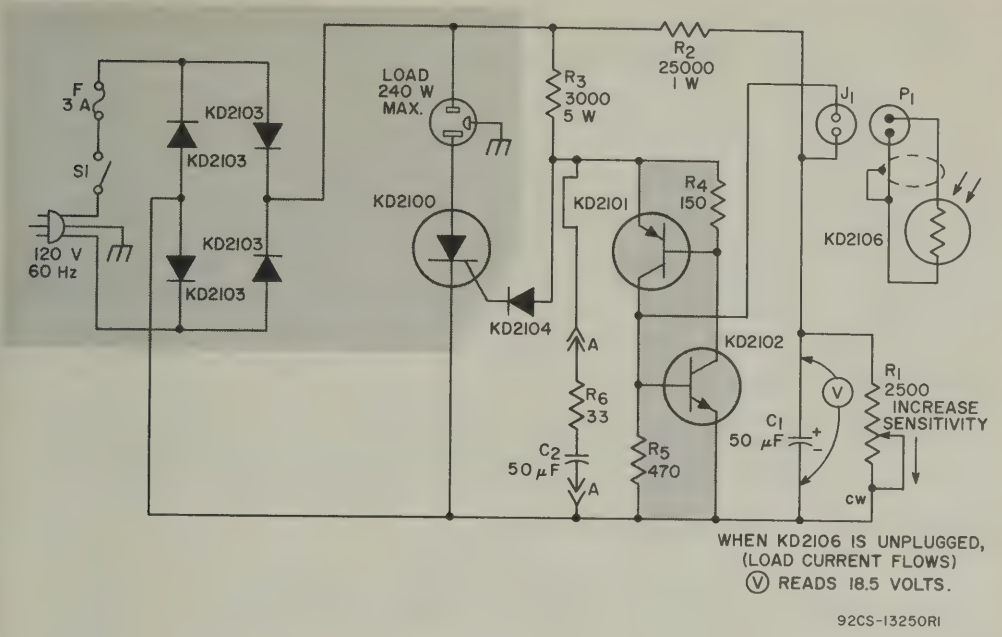


Fig. 79 — Photograph of Single-Kit Light-Operated Switch that turns off with increase in light (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Light-Operated Switch is shown in Fig. 80. The light level at which this circuit interrupts power to the load is adjusted by means of the sensitivity control



Basic chassis A (see Fig.17 for parts list
Connector, auto radio antenna, H.H. Smith
No.1300 or equivalent
Kit KD2106
Wire for photocell, any two-wire cord (lamp cord);
in exceptionally long runs use shielded cable.
C_1 = 50 microfarads, 150 volts, electrolytic
C_2* = 50 microfarads, 15 volts, electrolytic
J_1 = chassis connector, female, Amphenol
80-2 or equivalent
P_1 = cable connector, male, Amphenol
80-2 or equivalent
R_1 = potentiometer, 2500 ohms, 2 watts, linear
R_2 = 25,000 ohms, 1 watt
R_3 = 3000 ohms, 5 watts
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6* = 33 ohms, ½ watt
* Optional latching circuit parts

Fig. 80 — Schematic diagram of Single-Kit Light-Operated Switch that turns off with increase in light.

R_1. When the switch S_1 is closed, the SCR KD2100 is triggered into conduction by the current through resistor R_3 and the silicon diode KD2104, and load current flows immediately and continuously. (The SCR actually turns off at the end of each half-cycle of ac input and is re-triggered early in each succeeding half-cycle so that load current flows for almost the entire 360 degrees of each cycle.)

As in circuit No. 15, the resistors R_1 and R_2 and the capacitor C_1 function as a power source for the photocell KD2106. The sensitivity control R_1 is adjusted so that the potential on C_1 is

insufficient to supply the amount of current required to trigger the two-transistor regenerative switch. When the incident light level on KD2106 increases, however, the resistance of the photocell decreases, and the increased current through R_5 triggers the transistor switch. The gate current of the SCR is then shunted through the saturated transistors KD2101 and KD2102, and the SCR is not triggered into conduction on succeeding half-cycles of input until the light level decreases below the preset value. As in circuit No. 9, resistor R_3 functions as the load resistor for the SCR gate circuit.

If it is desired to have the load remain off once it is turned off by the switch, the "latching circuit" should be used. Wiring A in Fig. 80 designates this circuit.

ADJUSTMENTS AND SPECIAL PRECAUTIONS

The sensitivity of the circuit is adjusted prior to use by means of the potentiometer R_1. For maximum sensitivity, the control knob is turned in a clockwise direction until current ceases to flow in the load, and is then turned counterclockwise until load current just begins to flow. Further rotation in the counterclockwise direction reduces the sensitivity, i.e., capacitor C_1 charges to a lower potential and a greater amount of light is required to reduce the resistance of KD2106 enough to allow sufficient current through R_5 to trigger the transistor switch.

Because the power supplied to the load is rectified ac, this circuit should be used only with ac/dc loads such as incandescent lamps, heaters, and small universal motors.

Circuit No. 17—Twin-Kit Light-Operated Switch

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20), two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits,** and one **RCA Add-On Light-Sensor Experimenter's Kit KD2106.** Eleven additional resistors and two capacitors are mounted on the chassis, as shown in Fig. 81. If desired, a differential resistor can be added to increase the difference between the turn-on and turn-off light levels. The best range for a particular application can be determined by experiments with resistors of various values.

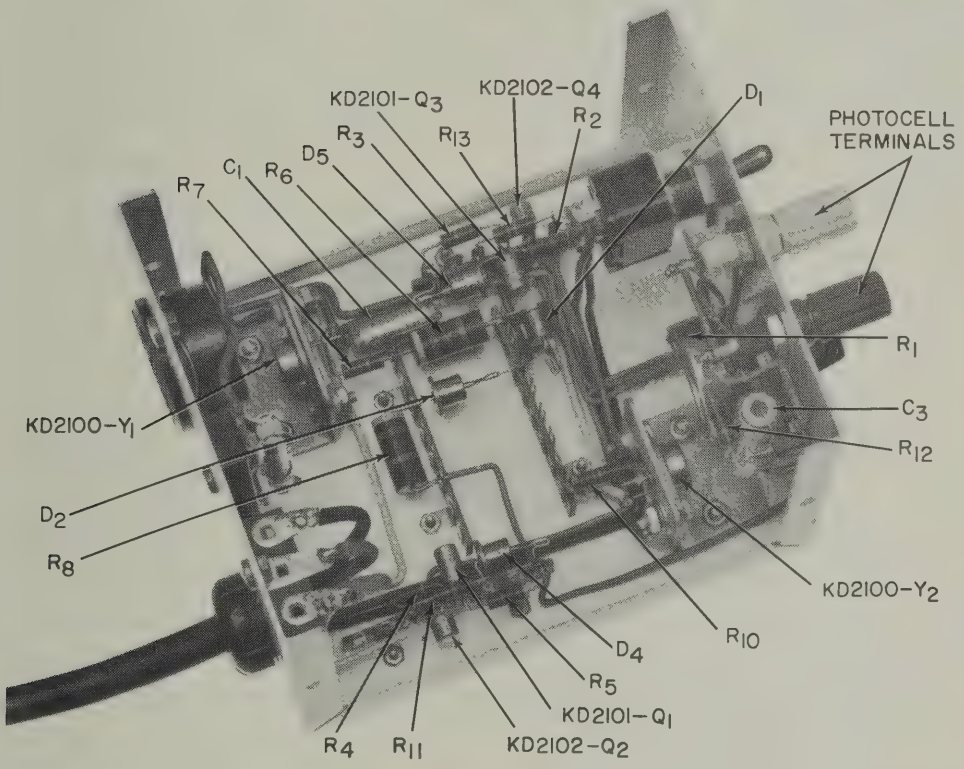
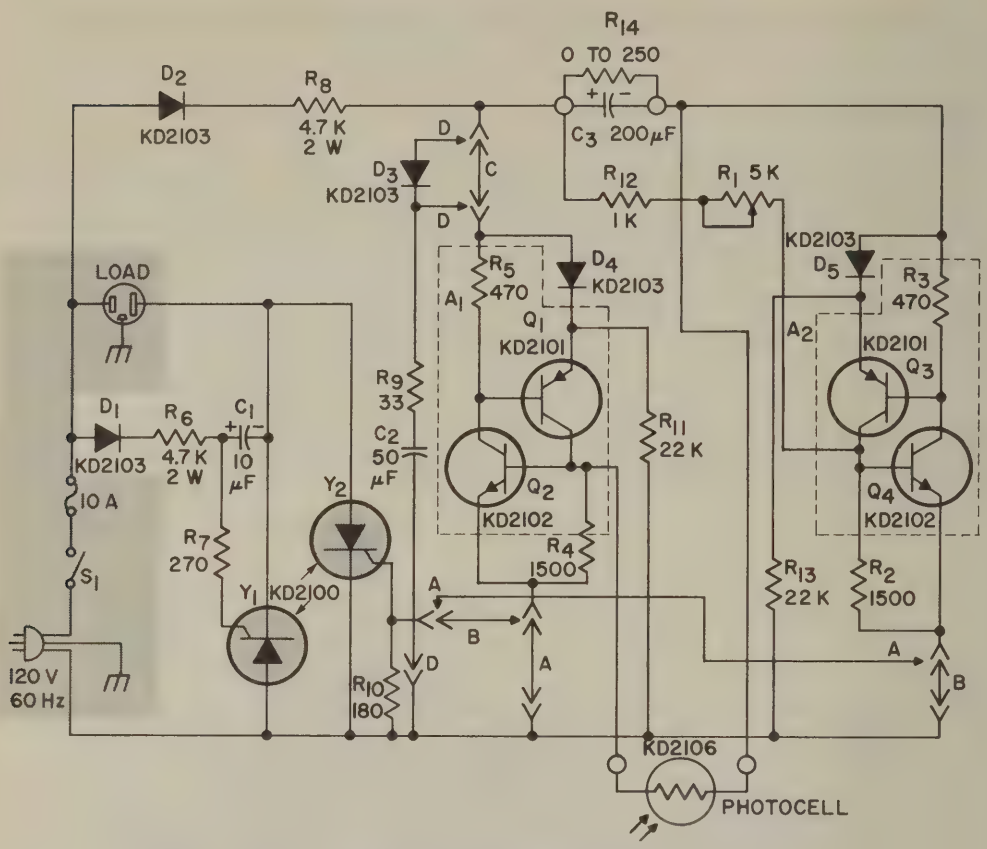


Fig. 81 — Photograph of Twin-Kit Light-Operated Switch (call-outs indicate components added to basic chassis).

The schematic diagram for this circuit is shown in Fig. 82. A number of methods are shown for wiring the circuit. When wiring A is used, an increase in light turns off the power to the load; when wiring B is used, an increase in light turns on the power to the load. When wiring C is used, the switch does not lock in either mode. For example, if wiring combination A and C is chosen, the power to the load is switched off with an increase in light level. The power is switched back on, however, when the



Basic chassis C (see Fig.20 for parts list).
Binding Posts, E.F. Johnson No.111-101 or equivalent; 2 required
Kit, KD2106
Terminal Strips, miniature, H.H. Smith No.1070 or equivalent; 2 required
Terminal Strip, miniature, H.H. Smith No.1063 or equivalent
C_1 = 10 microfarads, 15 volts, electrolytic
C_2* = 50 microfarads, 15 volts, electrolytic
C_3 = 200 microfarads, 6 volts, electrolytic
R_1 = potentiometer, 5000 ohms, 2 watts, linear
R_2, R_4 = 1500 ohms, ½ watt
R_3, R_5 = 470 ohms, ½ watt
R_6, R_8 = 4700 ohms, 2 watts
R_7 = 270 ohms, ½ watt
R_9* = 33 ohms, ½ watt
R_{10} = 180 ohms, ½ watt
R_{11}, R_{13} = 22,000 ohms, ½ watt
R_{12} = 1000 ohms, ½ watt
R_{14} = any resistance 0 to 250 ohms, ½ watt
* Optional latching circuit parts.

Fig. 82 — Schematic diagram of Twin-Kit Light-Operated Switch.

light level decreases below the value required to activate the switch. The A and C wiring combination can be used, therefore, to operate a night light (on at night, off during the day). If it is desirable for the power to remain on or off when the light level increases, wiring D (the "latching" circuit) should be used.

When the latching circuit is used, the light-operated switch locks in the load-power on or off mode until power to the switch unit is interrupted (i.e., until the switch unit is reset). The latching circuit operates by holding the regenerative switch in the conducting state after it has been triggered. When the latching circuit is used, the R_{14}, C_3 combination should be removed and replaced by a jumper.

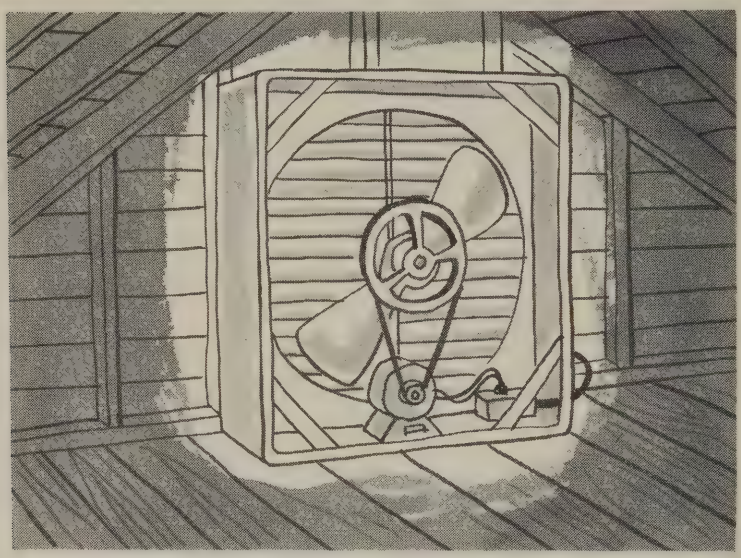
CIRCUIT OPERATION

When power is applied to the circuit, a voltage appears across the two regenerative switches A_1 and A_2 that control the signal voltage to the KD2100 Y_2. The triggering level of regenerative switch A_2 is set by resistor R_2 and the combination of R_1 and R_{12}. The triggering level of A_1 is set by R_4 and the photocell KD2106.

As the incident light level increases, the resistance of the photocell decreases, and thus the triggering level of regenerative switch A_1 decreases. If the triggering level of this switch is lower than that of switch A_2, and if the voltage is sufficient, the switch conducts on each positive half-cycle. If wiring A is used, the input to the SCR's is short-circuited; and the SCR's are non-conductive. If wiring B is used, a signal is applied to the gate of Y_2, that turns it on or causes it to conduct. Thus, a voltage is applied to the load and the network consisting of D_1, R_6, and C_1, causing C_1 to charge. During the next half-cycle, the charge on C_1 is applied to the gate of Y_1 and causes it to conduct. This process repeats as long as a signal is applied to the gate of Y_2 (i.e., until the light incident on the photocell is not sufficient to satisfy the requirements for which the switch is set).

When the incident light level decreases, the photocell resistance increases, and the triggering voltage applied to switch A_1 is increased. As a result, switch A_2 conducts a signal to the gate of Y_2 (if A wiring is used) or short-circuits the input of the SCR's (if wiring B is used). When switch A_2 conducts, a voltage appears across the differential resistor R_6 (if used). This drop causes a slight increase in the firing potential of switch A_1. The difference between the turn-on and turn-off light levels is increased by increasing the value of the differential resistor. If no difference in turn-on and turn-off light levels is required in the application, R_{14} and C_3 can be removed and replaced by a jumper.

ELECTRONIC HEAT CONTROLS



An application of an Electronic Heat Control is to operate an attic fan when home heat exceeds the comfort range.

Electronic heat controls are useful for activating space heaters, cooling fans, and warning alarms in food freezers; for switching on fire alarms; for controlling the temperature in fish tanks, incubators, and window greenhouses; or as safety devices for measuring the temperature in a furnace area or for shutting down hot or overheating motors. The circuits can also be used on farms to detect frost conditions.*

The two single-kit heat controls can switch loads that have power ratings up to 240 watts; the operating point of either circuit can be adjusted for temperatures ranging from −30 to 150°C (−22 to 302°F). One of the circuits switches the load on with an increase in temperature; the other switches the load off. The twin-kit circuit can handle loads up to one kilowatt and has an adjustable temperature range from −28 to 124°C (−18 to 255°F). The manner in which the twin-kit circuit is wired determines whether it turns the load on or off with increasing temperature.

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* For operation, construction, and safety precautions, refer to the section on *General Description and Application Considerations.*

Circuit No. 18—Single-Kit Electronic Heat Control (turns on with increase in temperature)

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18) in conjunction with the thermistors contained in the **RCA Add-On Heat-Sensor Experimenter's Kit KD2110.** (The three thermistors and suggested mounting arrangements are shown in Fig. 41.) Two additional resistors and an Amphenol microphone connector (for the thermistor) are mounted on the chassis as shown in Fig. 83; in addition, the fixed 150-ohm resistor normally used in the transistor regenerative switch is replaced by a 250-ohm variable resistor. Any reasonable length of microphone cable may be used with the heat sensor; the shield wire of the cable should be connected so that it terminates at the cathode of the SCR.

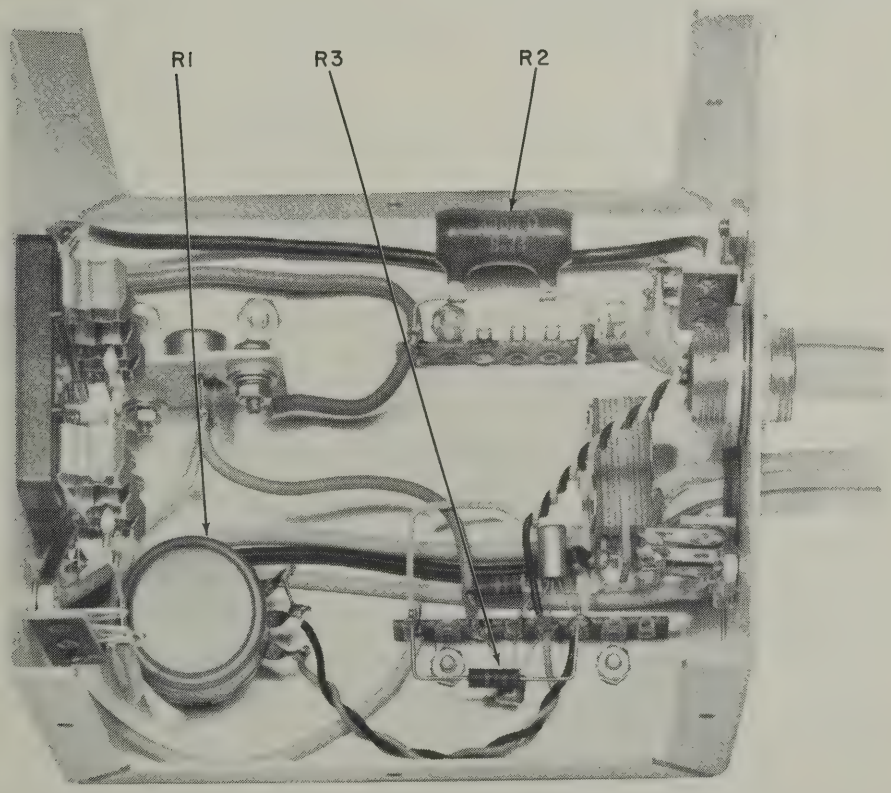
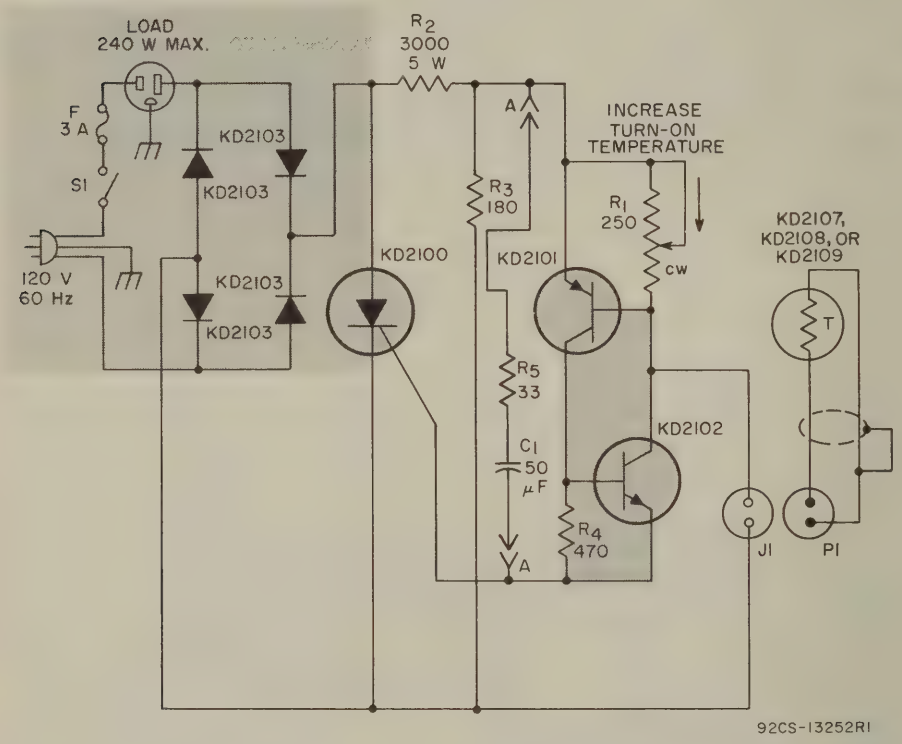


Fig. 83 — Photograph of Single-Kit Electronic Heat Control that turns on with increase in heat (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Electronic Heat Control is shown in Fig. 84. The temperature level at which this circuit applies power to the load is adjusted by means of the sensitivity control R_1, which determines the potential applied between the emitter and the base of transistor KD2101. When switch S_1 is closed, the current through R_2, R_1, and the thermistor is insufficient to trigger the two-transistor regenerative switch into conduction. Therefore, no signal is applied to the gate of the SCR



Basic chassis A (see Fig.17 for parts list)
Kit, KD2110
Microphone cable, 15 feet, shielded
C_1* = 50 microfarads, 15 volts, electrolytic
J_1 = chassis connector, female, Amphenol 80-2 or equivalent
P_1 = cable connector, male, Amphenol 80-2 or equivalent
R_1 = potentiometer, 250 ohms, 2 watts, linear
R_2 = 3000 ohms, 5 watts
R_3 = 180 ohms, ½ watt
R_4 = 470 ohms, ½ watt
R_5* = 33 ohms, ½ watt
* Optional latching circuit parts

Fig. 84 — Schematic diagram of Single-Kit Electronic Heat Control that turns on with increase in heat.

KD2100, and practically no load current flows. As the ambient temperature increases, however, the resistance of the thermistor decreases (because the thermistor has a negative temperature coefficient of resistance) and the current through R_1 increases. When the temperature reaches the minimum pre-set level, the drop across R_1 is sufficient to trigger the regenerative switch into conduction. The switch, in turn, triggers the SCR to complete the load circuit. As long as the temperature remains above the pre-set level, the transistor switch and the SCR are re-triggered early in each succeeding half-cycle of ac input; load current then flows for essentially the full 180 degrees of each half-cycle.

When the temperature level decreases below the minimum pre-set level, the resistance of the thermistor again increases and the voltage drop across R_1 decreases below the level required to trigger the transistor switch into conduction on the following half-cycle of ac input. The SCR is then not triggered into conduction during succeeding input half-cycles until the next increase in temperature.

If it is desired to have the load remain on once the switch has turned it on, the "latching circuit" indicated by wiring A in Fig. 84 should be used.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The sensitivity of the circuit is adjusted prior to use by means of the potentiometer R_1 for the particular thermistor selected. The **Add-On Heat-Sensor Experimenter's Kit KD2110** contains three thermistors which cover a temperature range from —30 to 150°C (—22 to 302°F). With the applicable thermistor KD2107, KD2108, or KD2109 connected to the circuit, the control knob is turned in a clockwise direction until the load conducts current, and is then turned counterclockwise until the load just stops conducting. Further rotation in the counterclockwise direction reduces the sensitivity, i.e., the resistance between the emitter and the base of transistor KD2101 is decreased and a larger increase in temperature is required to reduce the thermistor resistance sufficiently to trigger the regenerative switch.

Care should be employed to ensure that the thermistor is insulated from the frame or housing of the appliance or device to which it is attached. Because the load is connected on the line side of the rectifier bridge, this circuit can be used with any ac-operated device having a power rating up to 240 watts.

Circuit No. 19—Single-Kit Electronic Heat Control (turns off with increase in temperature)

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18) in conjunction with the thermistors contained in the **RCA Add-On Heat-Sensor Experimenter's Kit KD2110.** (The three thermistors and suggested mounting arrangements are shown in Fig. 41.) Two additional resistors, a silicon rectifier KD2104, and an Amphenol microphone connector (for the thermistor) are mounted on the chassis as shown in Fig. 85; in addition, the fixed 150-ohm resistor normally used in the transistor regenerative switch is replaced by a variable 250-ohm resistor. An additional hole is drilled in the chassis for mounting of the microphone connector. Any reasonable length of microphone cable may be used with the thermistor; the shield wire of the cable should be connected so that it terminates at the cathode of the SCR.

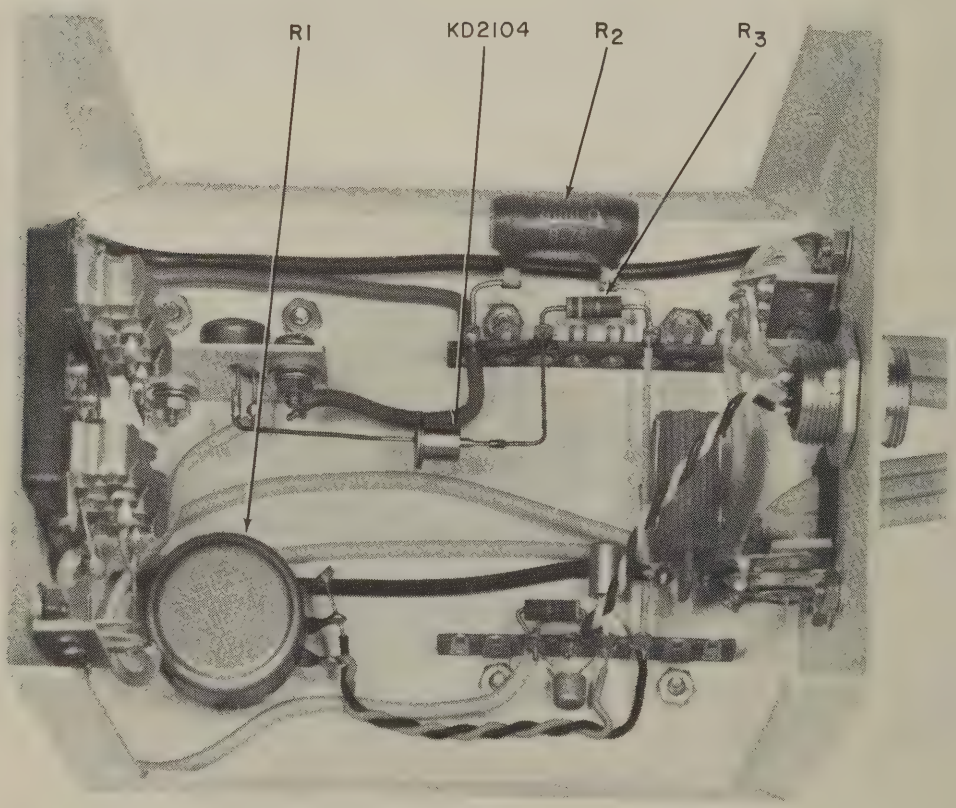
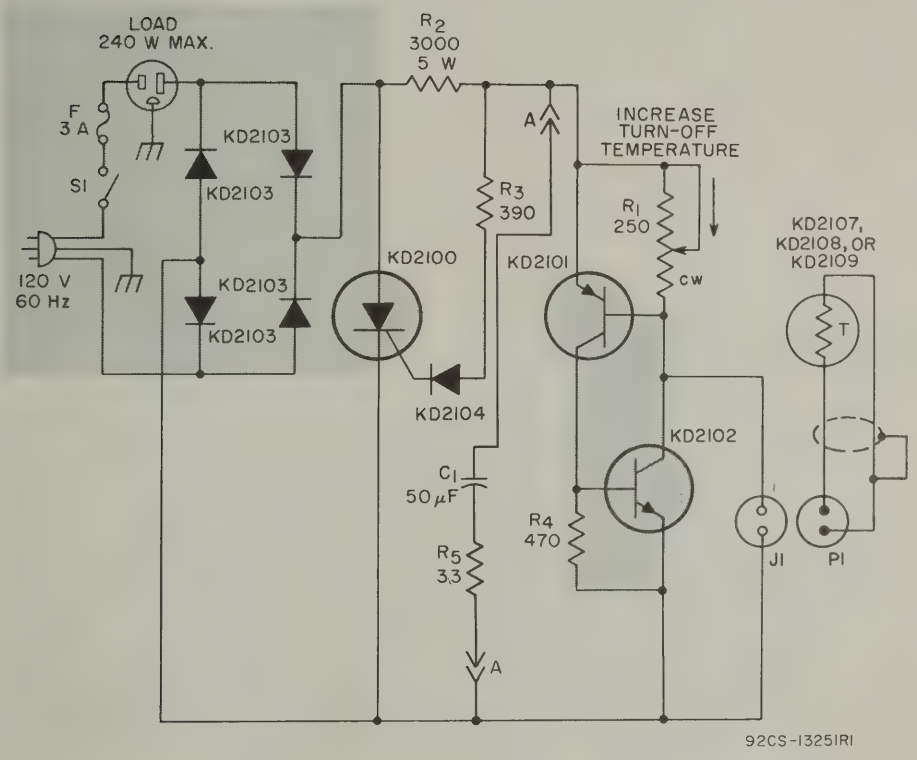


Fig. 85 — Photograph of Single-Kit Electronic Heat Control that turns off with increase in heat (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Electronic Heat Control is shown in Fig. 86. The temperature level at which this circuit interrupts power to the load is adjusted by means of the sensitivity control R_1, which determines the amount of resistance between the emitter and the base of transistor KD2101. When



Basic chassis A (see Fig.17 for parts list)
Kit, KD2110
Microphone cable, 15 feet shielded
C_1* = 50 microfarads, 15 volts, electrolytic
J_1 = chassis connector, female, Amphenol 80-2 or equivalent
P_1 = cable connector, male, Amphenol 80-2 or equivalent
R_1 = potentiometer, 250 ohms, 2 watt, linear
R_2 = 3000 ohms, 5 watts
R_3 = 390 ohms, ½ watt
R_4 = 470 ohms, ½ watt
R_5* = 33 ohms, ½ watt
* Optional latching circuit parts

Fig. 86 — Schematic diagram of Single-Kit Electronic Heat Control that turns off with increase in heat.

the switch S_1 is closed, the SCR KD2100 is triggered into conduction by the current through resistors R_2 and R_3 and the silicon diode KD2104, and load current flows immediately and continuously. (The SCR actually turns off at the end of each half-cycle of ac input and is retriggered early in each succeeding half-cycle so that load current flows for almost the entire 360 degrees of each cycle.)

As in circuit No. 18, the current through resistors R_2 and R_1 and the thermistor is normally insufficient to trigger the two-transistor regenerative switch into conduction. As the ambient temperature increases, however, the resistance of the thermistor decreases (because the thermistor has a negative temperature coefficient of resistance) and the current through R_1 increases. When the temperature reaches the minimum pre-set level, the drop across R_1 is sufficient to trigger the regenerative switch into conduction. The gate current of the SCR is then shunted through the saturated transistors KD2101 and KD2102, and the SCR is not triggered into conduction on succeeding half-cycles of input until the temperature level decreases below the pre-set value.

If it is desired to have the load remain off after it is turned off by the switch, the "latching circuit" designated by wiring A in Fig. 86 should be used.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

The sensitivity of this circuit, like that of circuit No. 18, is adjusted prior to use by means of potentiometer R_1 for the particular thermistor selected. The **Add-On Heat-Sensor Experimenter's Kit KD2110** contains three thermistors which cover a temperature range from −30 to 150°C (−22 to 302°F). With the applicable thermistor KD2107, KD2108, or KD2109 connected to the circuit, the control knob is turned in a clockwise direction until current ceases to flow in the load, and is then turned counterclockwise until load current just begins to flow. Further rotation in the counterclockwise direction reduces the sensitivity, i.e., the resistance between the emitter and the base of transistor KD2101 is decreased and a larger increase in temperature is required to reduce the thermistor resistance sufficiently to trigger the regenerative switch.

Care should be employed to ensure that the thermistor is insulated from the frame or housing of the appliance or device to which it is attached. Because the load is connected on the line side of the rectifier bridge, this circuit can be used with any ac-operated device having a power rating up to 240 watts.

Circuit No. 20—Twin-Kit Electronic Heat Control

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20), one **RCA Add-On Heat-Sensor Experimenter's Kit KD2110,** and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Eleven additional resistors and two capacitors are mounted on the chassis, as shown in Fig. 87. If desired, a differential resistor can be added to increase the difference between the turn-on and turn-off temperatures. If no difference is desired, R_{14} and C_3 can be removed and replaced by a jumper. The best range for a particular application can be determined by experiments with resistors of various values.

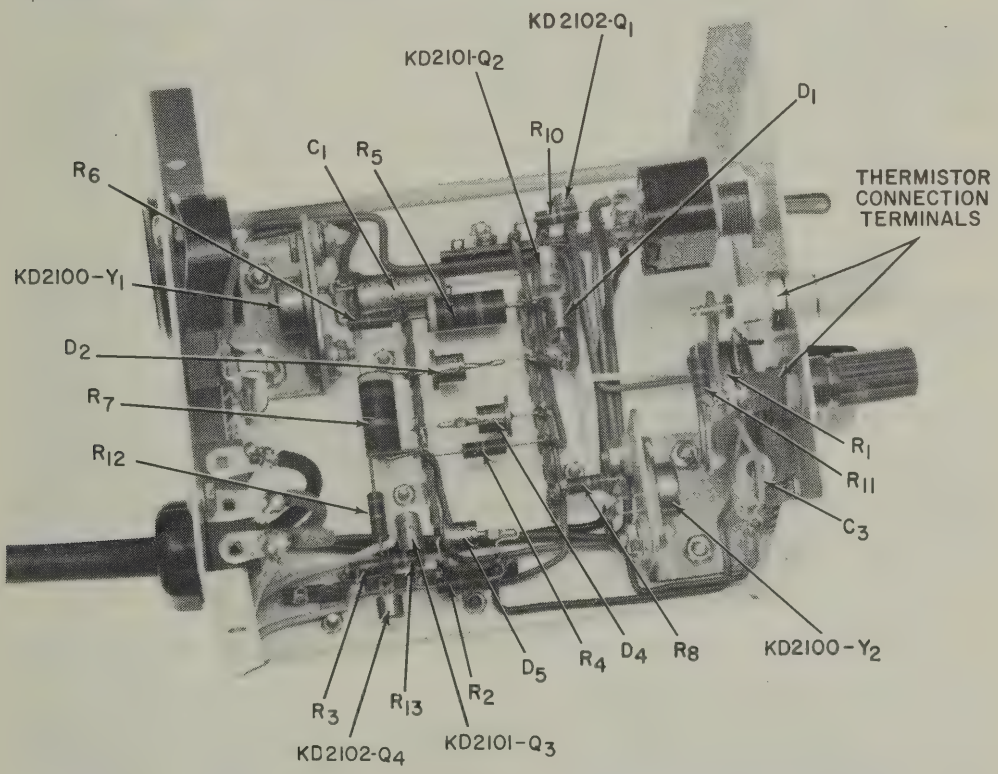


Fig. 87 — Photograph of Twin-Kit Electronic Heat Control (call-outs indicate components added to basic chassis).

The operating-temperature range of the electronic heat controls depends on the thermistor used. The useful temperature range of the KD2107 thermistor is between −28°C (−18°F) and 40°C (104°F); the useful range of the KD2108 thermistor is 35°C (95°F) to 124°C (255°F). The KD2109 thermistor is not compatible with the design of this circuit and should not be used; the full temperature range of the circuit can be realized by use of the KD2107 and KD2108.

CIRCUIT OPERATION

The schematic diagram for the Twin-Kit Electronic Heat Control is shown in Fig. 88. Four different methods for wiring the circuit are shown. Wiring A causes the circuit to the load to be opened as the temperature increases; wiring B causes the opposite effect, i.e., an open circuit to the load with a decrease in temperature. When the wiring designated C is used, the circuit does not lock in either mode. The wiring D "latches" or locks the control in the load-circuit open or closed position, depending on whether wiring A or B is chosen. When wiring D (the latching circuit) is used, R_{14} and C_3 should be removed and replaced by a jumper.

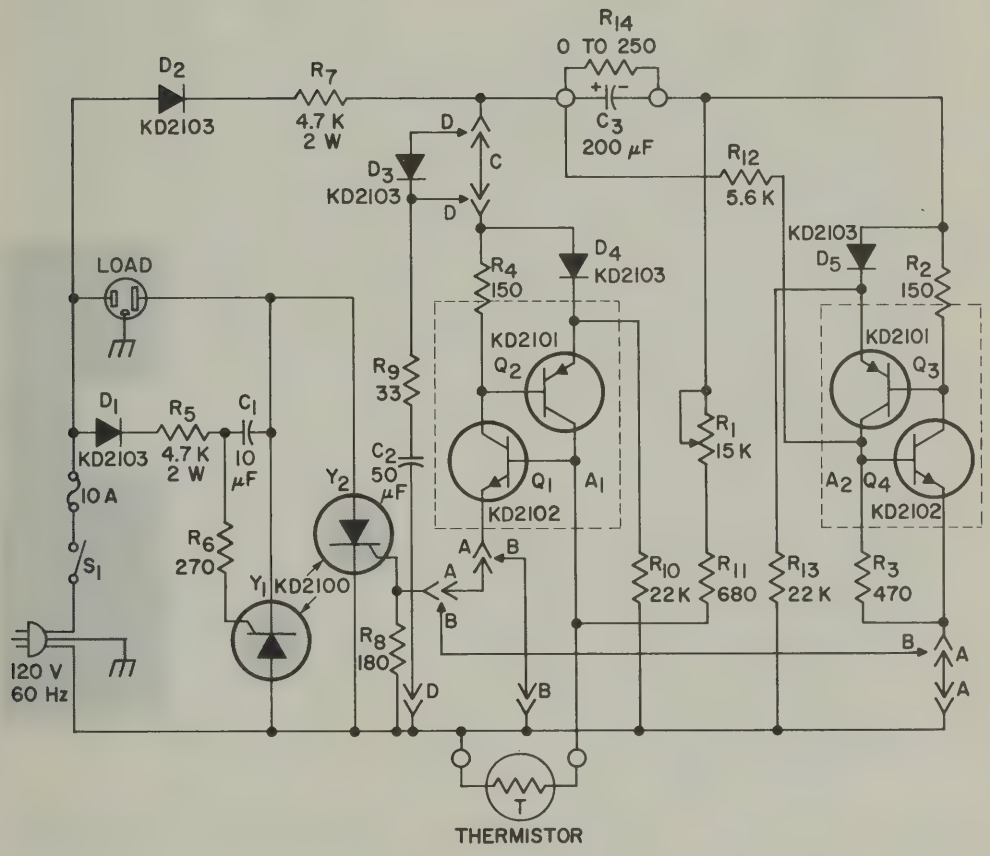
The useful range of the Twin-Kit Electronic Heat Control depends, as described previously, on the thermistor used. This range can be varied by changing the values of potentiometer R_1 and resistor R_{11} in series with it. The total resistance of this combination should never exceed 18,000 ohms; the resistance of R_{11} should never be less than 680 ohms.

When power is applied to the circuit, a voltage is applied to the two regenerative switches that control the signal or gate voltage to the SCR's. The triggering level of regenerative switch A_2 is set by the fixed resistors R_3 and R_{12}. The triggering level of A_1 is set by the thermistor and the series combination of R_{11} and the potentiometer R_1. The triggering level of the individual regenerative switches is determined by their associated resistances and not by the voltage across them. As a result, the switching of the circuit is independent of changes in line voltage.

When the ambient heat around the thermistor is high, the resistance of the thermistor is low and the voltage required to trigger switch A_1 is high. If this triggering voltage is higher than that required by A_2, switch A_2 conducts. When wiring A is used, the signal from A_2 is short-circuited and there is an open circuit to the load. If differential resistor R_{14} is used, the current through switch A_2 causes a voltage drop across R_{14}. This drop results in a slight increase in the firing potential of switch A_1. Because R_{14} controls the firing potential of A_1, it also controls the turn-on and turn-off temperatures of the circuit. With a decrease in temperature, the resistance of the thermistor increases and thus reduces the potential required to fire A_1. This switch turns on when its firing potential is lower than that of switch A_2 and applies a signal to the gate of Y_2 to turn it on (when wiring A is used).

A voltage is then applied to the load and to the network consisting of D_1, R_5, and C_1, causing C_1 to charge.

During the next half-cycle, the charge on C_1 is applied to the gate of Y_1, causing it to conduct current to the load. If wiring A is used, this process repeats as long as the thermistor is cool; if wiring B is used, as long as the thermistor is warm.

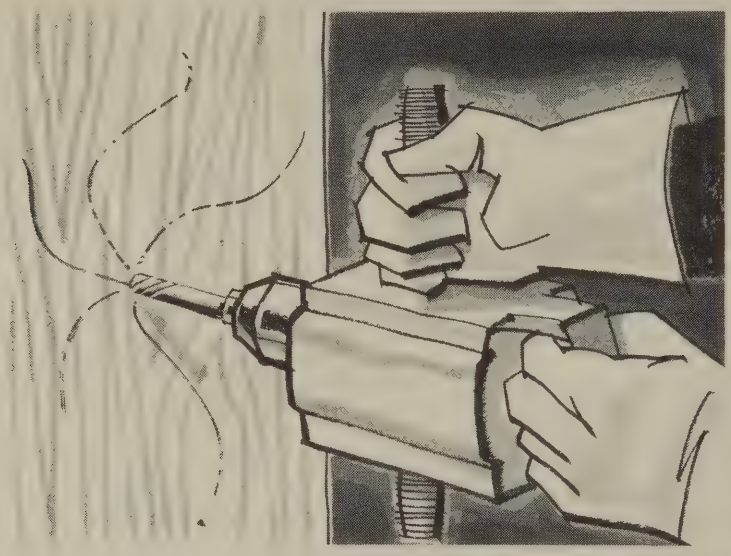


Basic chassis C (see Fig.20 for parts list)
Binding posts, E.F. Johnson No.111-101 or equivalent, 2 required
Kit, KD2110
Terminal strips, miniature, H.H. Smith No.1070 or equivalent, 2 required
Terminal strip, miniature, H.H. Smith No.1063 or equivalent
C_1 = 10 microfarads, 15 volts, electrolytic
C_2* = 50 microfarads, 15 volts, electrolytic
C_3 = 50 microfarads, 6 volts, electrolytic
R_1 = potentiometer, 15,000 ohms, 2 watts, linear
R_2, R_4 = 150 ohms, ½ watt
R_3 = 470 ohms, ½ watt
R_5, R_7 = 4700 ohms, 2 watts
R_6 = 270 ohms, ½ watt
R_8 = 180 ohms, ½ watt
R_9* = 33 ohms, ½ watt
R_{10}, R_{13} = 22,000 ohms, ½ watt
R_{11} = 680 ohms, ½ watt
R_{12} = 5600 ohms, ½ watt
R_{14} = any resistance 0 to 250 ohms, ½ watt

*Optional latching circuit parts

Fig. 88 — Schematic diagram of Twin-Kit Electronic Heat Control.

OVERLOAD SWITCHES



An application of the Overload Switch is to protect an electric drill from overload current or to protect the material being worked from excess pressure.

The Single-Kit and Twin-Kit Overload Switch circuits are useful in applications in which a motor is to be turned off when a certain load is reached or in which it is desirable to determine the load on a motor. A good example of the latter application is the use of these circuits to turn off a food mixer when batter reaches the desired consistency. Another common application for these circuits is to prevent overload current in saber saws, electric drills and sanders, and other power tools.

Both overload-switch circuits are fast-acting electronic circuit breakers, faster than mechanical circuit breakers or fuses. The switches interrupt power to ac/dc loads when the current exceeds a pre-set value. Additional features of the Twin-Kit circuit are that it does not arc at cut-out, and therefore does not cause radio-frequency interference, and that it handles loads up to one kilowatt.*

The "tripping"-current range is 0.75 to 2 amperes for the Single-Kit circuit for all loads; for the Twin-Kit circuit, it is 1.5 to 6 amperes for incandescent-lamp loads and 1.5 to 8 amperes for all other loads.

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

Circuit No. 21—Single-Kit Overload Switch

CONSTRUCTION

The circuit uses the basic chassis A (shown in Figs. 17 and 18); four additional resistors, one capacitor, and a silicon rectifier KD2104 are mounted on the chassis as shown in Fig. 89. No additional holes are required in the chassis for this circuit.

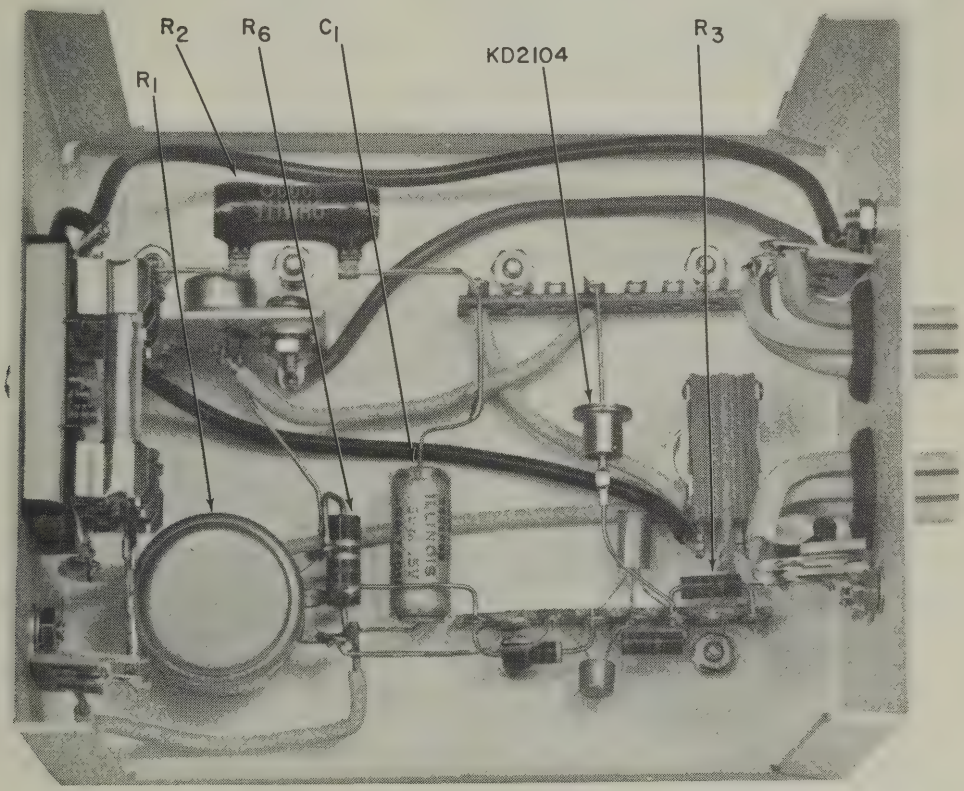
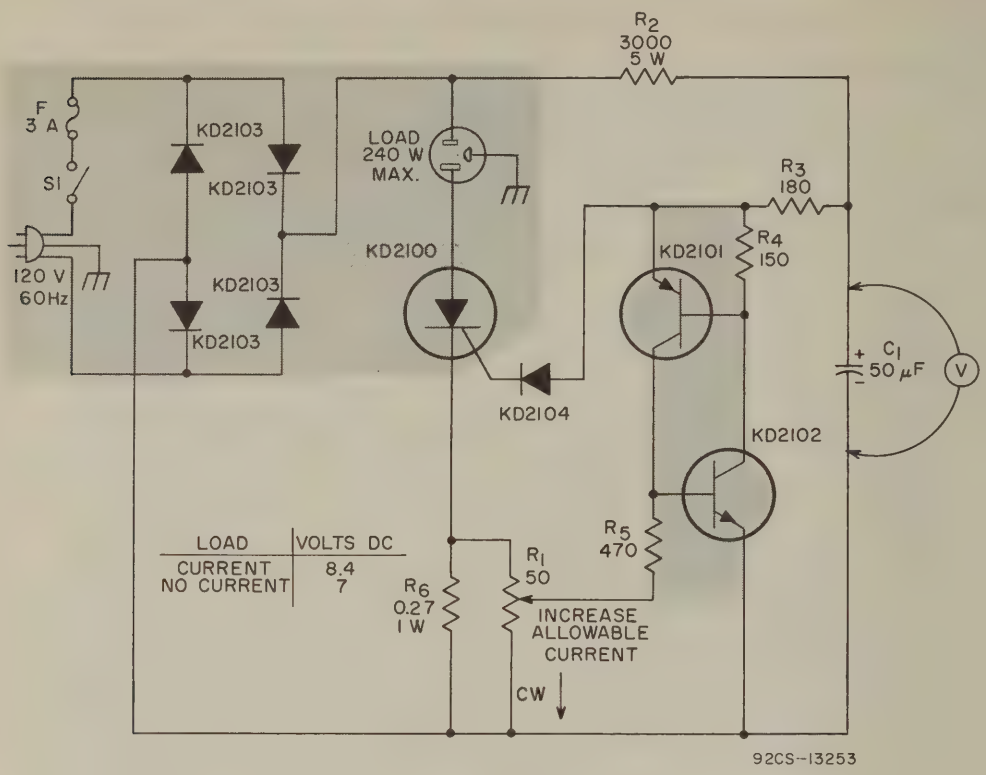


Fig. 89 — Photograph of Single-Kit Overload Switch (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Overload Switch is shown in Fig. 90. The current at which this circuit interrupts power to the load is pre-set by adjustment of the potentiometer R_1. When the switch S_1 is closed, the pulsating direct current from the bridge rectifiers KD2103 charges capacitor C_1 through resistor R_2. The potential on C_1 maintains a steady current through resistor R_3 and the silicon diode KD2104 which is sufficient to trigger the SCR KD2100 early in each input half-cycle; as a result, current flows through the load over the maximum possible conduction angle.

The value of resistor R_6 is selected so that load current continues to flow for currents up to two amperes when R_1 is set



Basic chassis A (see Fig.17 for parts list).
C_1 = 50 microfarads, 15 volts, electrolytic
R_1 = potentiometer, 50 ohms, 2 watts, linear
R_2 = 3000 ohms, 5 watts
R_3 = 180 ohms, ½ watt
R_4 = 150 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_6 = 0.27 ohm, 1 watt

Fig. 90 — Schematic diagram of Single-Kit Overload Switch.

near its mid-range position. Below two amperes, the voltage between the wiper arm and the clockwise end of potentiometer R_1 (which is the signal between the base and the emitter of transistor KD2102) is insufficient to cause conduction of KD2102 and thus to trigger the regenerative switch. When the load current exceeds two amperes, however, the input signal from R_1 triggers the regenerative switch; the gate current to the SCR is then shunted and current through the SCR to the load is interrupted. The charge on capacitor C_1 holds the transistor switch in full conduction so that the SCR cannot be re-triggered on succeeding input half-cycles until the switch S_1 is opened long enough for C_1 to discharge completely, and is then closed again. Rotation of the control knob in the counterclockwise direction causes turn-off at smaller load currents.

ADJUSTMENTS AND SPECIAL CONSIDERATIONS

As mentioned previously, the value shown for resistor R_6 permits the circuit to be set for a "tripping" current of two amperes with the control knob at mid-range position and for 0.75 ampere in the maximum counterclockwise position. The circuit can be made more sensitive (i.e., the turn-off current can be reduced below 0.75 ampere) by use of a larger resistance value for R_6. A value of 0.47 ohm (2 watts) increases the sensitivity to 425 milliamperes; a value of 1 ohm (5 watts) reduces the critical current to approximately 200 milliamperes.

Because the load is connected on the dc side of the bridge rectifier, this overload-protection circuit should be used only with ac/dc loads such as universal motors and heaters. Incandescent lamps can be protected against overload currents provided the control knob is turned to the maximum clockwise position before the switch S_1 is closed. This setting prevents the starting transient caused by the low cold resistance of the lamp from triggering the regenerative switch and interrupting current to the load. After the lamp brightens, the control knob should be turned counterclockwise to the setting for two amperes (or the desired "tripping" current). Photoflood lamps cannot be used with this circuit, even with such a precautionary procedure, because their extremely low cold resistance would cause the fuse to blow.

Circuit No. 22—Twin-Kit Overload Switch

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Thirteen additional resistors and four capacitors are mounted on the chassis as shown in Fig. 91. Resistor R_6 is home-made; it consists of 10 feet of No. 22 wire noninductively wound.

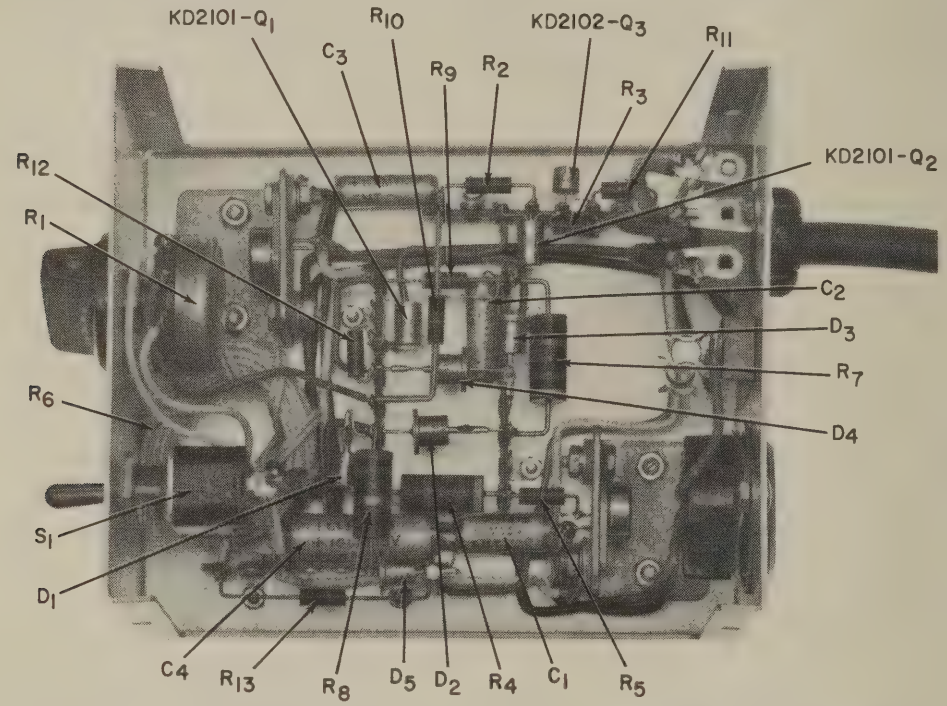


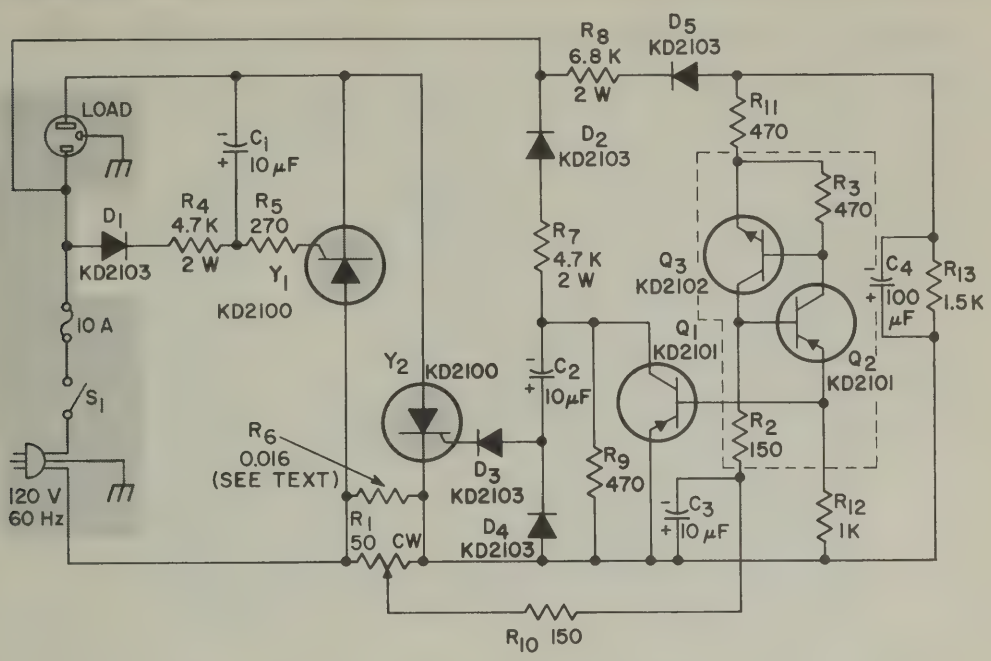
Fig. 91 — Photograph of Twin-Kit Synchronous Overload Switch (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this Twin-Kit Synchronous Overload Switch is shown in Fig. 92. When switch S_1 is closed, capacitor C_2 is charged through resistor R_7 and diodes D_2 and D_4 when the diodes are forward-biased by the power source.

On the following half-cycle, the charge on C_2 is applied to the gate of the SCR Y_2 and turns it on. The voltage placed across the load during this half-cycle is also applied to the combination of D_1, R_4, and C_1, and causes the latter to charge. The residual charge on this capacitor turns on the SCR Y_1 during the next half-cycle. This process repeats as long as the KD2101 transistor Q_1 is not conducting (i.e., when there is no overload condition).

An overload condition exists when the current drawn by the



Basic chassis C (see Fig.20 for parts list)
Terminal strips, miniature, H.H. Smith No.1070
or equivalent; 2 required
C_1, C_2, C_3 = 10 microfarads, 15 volts, electrolytic
C_4 = 100 microfarads, 12 volts, electrolytic
R_1 = potentiometer, 50 ohms, 2 watts, linear
R_2, R_{10} = 150 ohms, ½ watt
R_3, R_9, R_{11} = 470 ohms, ½ watt
R_4, R_7 = 4700 ohms, 2 watts
R_5 = 270 ohms, ½ watt
R_6 = 0.165 ohm, 10 feet No.22 wire
non-inductively wound
R_8 = 6800 ohms, 2 watts
R_{12} = 1000 ohms, ½ watt
R_{13} = 1500 ohms, ½ watt

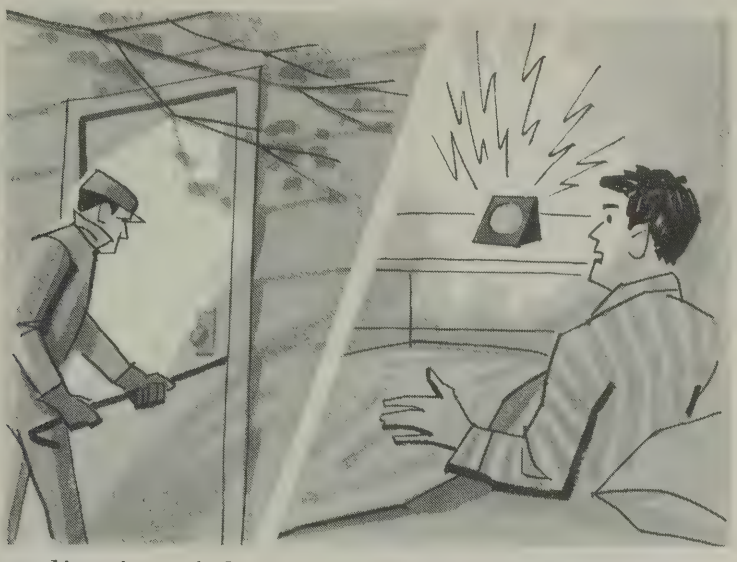
Fig. 92 — Schematic diagram of Twin-Kit Synchronous Overload Switch.

load is sufficient to cause the regenerative switch to conduct. The triggering potential of this switch is set by the potentiometer. The potentiometer R_1 in combination with R_6 forms a sensing resistance that detects the increasing current to the load. When the current through this combination reaches a value high enough to make the base of regenerative-switch transistor Q_2 negative with respect to its emitter, the regenerative switch is able to conduct. The voltage across the switch is derived from C_4, which is charged through R_8 and D_5 by the power source. When the regenerative switch conducts, it turns on the KD2101 transistor Q_1 by making its base more negative with respect to its emitter. When Q_1 conducts, the charging path for C_2 is bypassed.

If this capacitor cannot charge, Y_2 cannot be turned on. As a result, the circuit to the load is opened for the first half-cycle. Then, because there is no voltage across the load for the first half-cycle, capacitor C_1 cannot charge and subsequently turn on Y_1 during the next half-cycle. The result is that the circuit to the load is opened and the load receives no power.

Because the sustaining potential for the regenerative switch is very low, it conducts after it is triggered as long as power is applied to the circuit. To reset the overload-switch circuit, therefore, it is necessary to operate the power switch momentarily.

Circuit No. 23—Audio-Frequency-Operated Switch



An application of the Audio-Frequency-Operated Switch is to turn on an alarm when noise signals the presence of an intruder.

This Twin-Kit circuit can be used to turn on a load rated up to one kilowatt when the sound level increases above a certain predetermined level. The load continues to receive power until the sound level drops below the predetermined level. The circuit can be activated by sounds such as nursery or intruder noise, and can be used to turn radio transmitters and remote intercoms on and off. It can also be used to measure noise level; in such applications, it activates some device when a predetermined noise level is reached. The level of input to this switch should be approximately 1 volt and should come from the output of a pre-amplifier, an amplifier, or a radio or TV receiver.*

CONSTRUCTION

The circuit uses basic chassis C (shown in Fig. 20) and two KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits. Five additional resistors, three capacitors, two diodes, and two binding posts are mounted on the chassis as shown in Fig. 93.

CIRCUIT OPERATION

The schematic diagram for this Audio-Frequency-Operated Switch is shown in Fig. 94. The audio- or radio-frequency signal applied to the input terminals is rectified by the 1N34A diodes D_5

* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

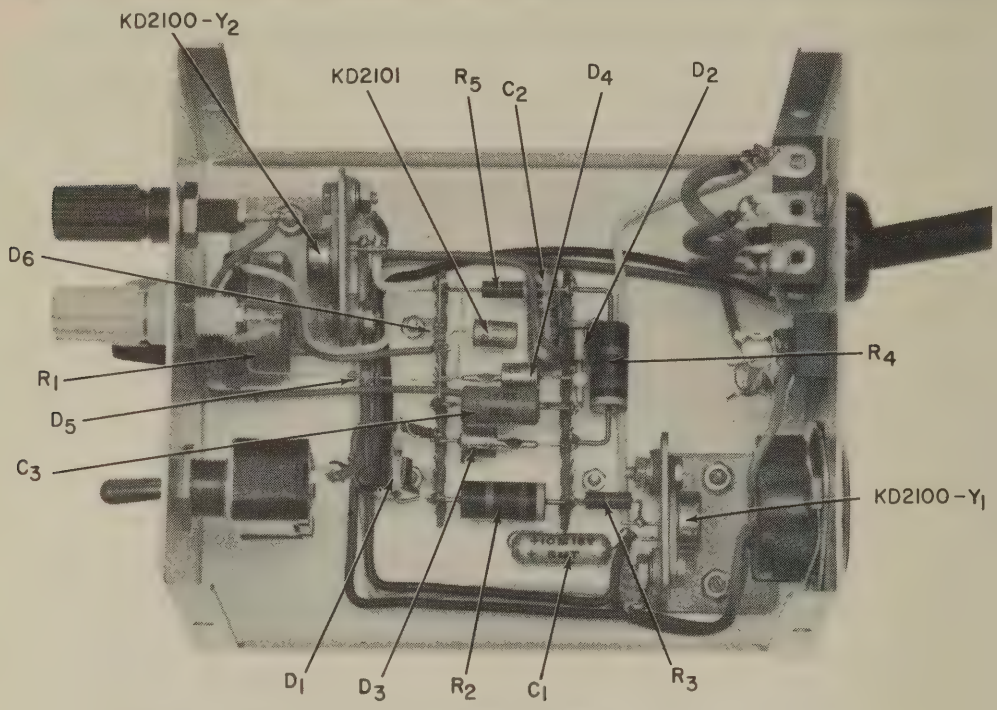


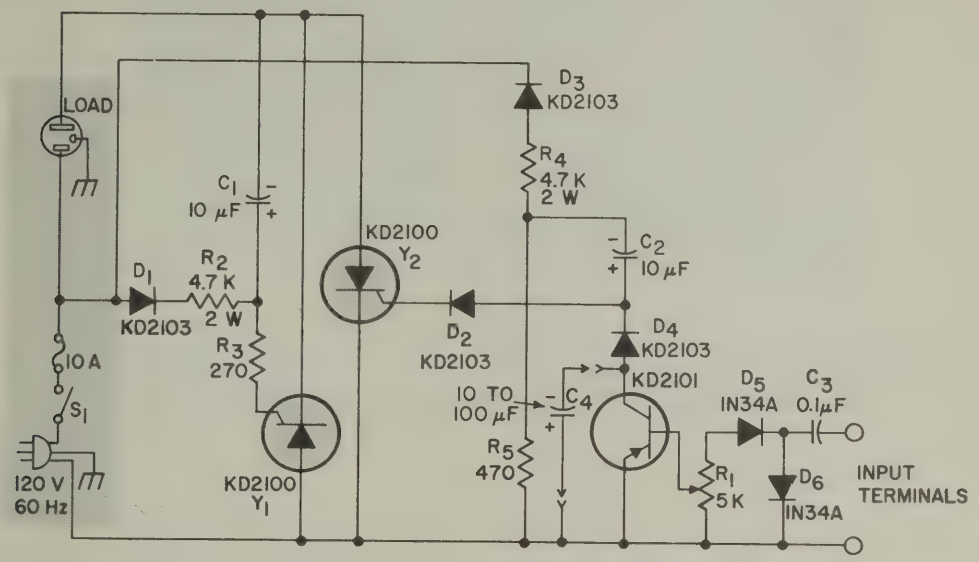
Fig. 93 — Photograph of Twin-Kit Audio-Frequency-Operated Switch (call-outs indicate components added to basic chassis).

and D_6. The resulting signal is applied to the base of the KD2101 transistor through the potentiometer R_1. The amount of noise required to activate the circuit can be controlled by adjustment of the potentiometer. The signal applied to the base of the KD2101 causes it to conduct, provided that switch S_1 is closed so that the KD2101 emitter is positive. The current conducted by KD2101 charges C_2 through the charging path D_3, D_4, and R_4.

On the following half-cycle, the charge on capacitor C_2 is applied to the gate of the SCR Y_2 and turns it on; a voltage is thus placed across the load. The load voltage is also applied to the combination of D_1, R_2, and C_1, and causes the capacitor to charge. The charge on C_1 turns on Y_1 during the next half-cycle. This process repeats as long as there is a sufficient audio- or radio-frequency signal present at the input terminals to cause the KD2101 to conduct.

When the signal is removed, the KD2101 transistor becomes nonconductive; the charging path for capacitor C_2 is thus opened. If C_2 cannot charge, Y_2 cannot turn on. The result is an open circuit to the load. Because there is no voltage across the load, capacitor C_1 cannot obtain the charge it needs to turn on Y_1 during the next half-cycle. Therefore, both SCR's remain off until another signal is received at the input terminals.

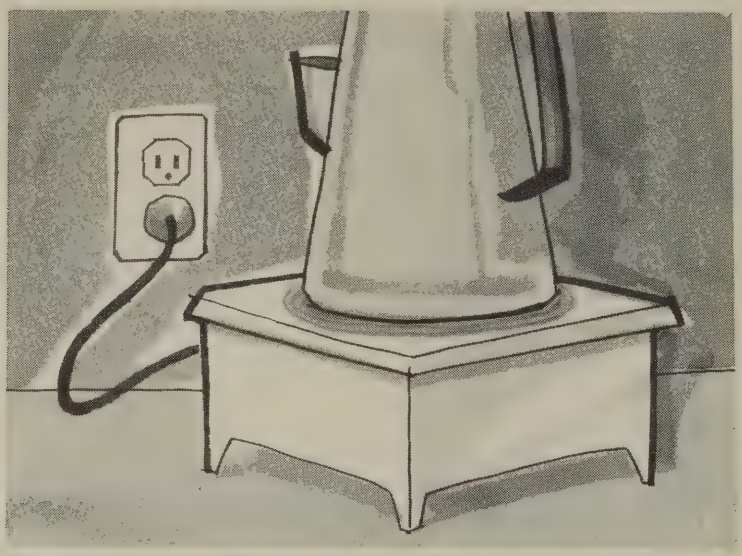
The release time, or the time that it takes for the switch to turn off after the input signal ceases, can be increased so that the switch does not open during momentary interruptions (e.g., between syllables). This increase in release time is accomplished by connection of a capacitor between the emitter and the collector of the KD2101. Values of capacitance up to 100 microfarads (15 volts) can be used.



Basic chassis C (see Fig.20 for parts list)
Binding posts, E.F. Johnson No.111-101
or equivalent; 2 required
C_1, C_2 = 10 microfarads, 15 volts, electrolytic
C_3 = 0.1 microfarad, 200 volt, any type
C_4 = 10 to 100 microfarads, 12 volts, electrolytic; to increase release time.
D_5, D_6 = 1N34A diodes
R_1 = potentiometer, 5000 ohms, 2 watts, linear
R_2, R_4 = 4700 ohms, 2 watts
R_3 = 270 ohms, ½ watt
R_5 = 470 ohms, ½ watt

Fig. 94 — Schematic diagram of Audio-Frequency-Operated Switch.

Circuit No. 24—Heater Power Control



An application of the Heater Power Control is to regulate the amount of power delivered to a hot plate so that coffee can be boiled or just kept warm.

This Twin-Kit circuit can control heaters, hot plates, space heaters, electric blankets, soldering irons, and similar loads that have power ratings up to one kilowatt. It is basically a ratio switch, i.e., it can be set for a certain ratio of conducting time to nonconducting time by manipulation of the potentiometer, and thus allows current to flow to the load for controlled periods of time.The Heater-Power Control is designed to operate over a power-conduction range from 5 to 95 per cent. It switches current only when the input ac voltage wave passes through the zero point. This feature effectively prevents radio-frequency interference and makes the circuit an excellent heat controller.*

CONSTRUCTION

This circuit uses basic chassis C (shown in Fig. 20) and two **KD2105 RCA Silicon Controlled Rectifier Experimenter's Kits.** Eleven additional resistors and five capacitors are mounted on the chassis as shown in Fig. 95.

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* For operation, construction, and safety precautions, refer to the previous section on *General Description and Application Considerations.*

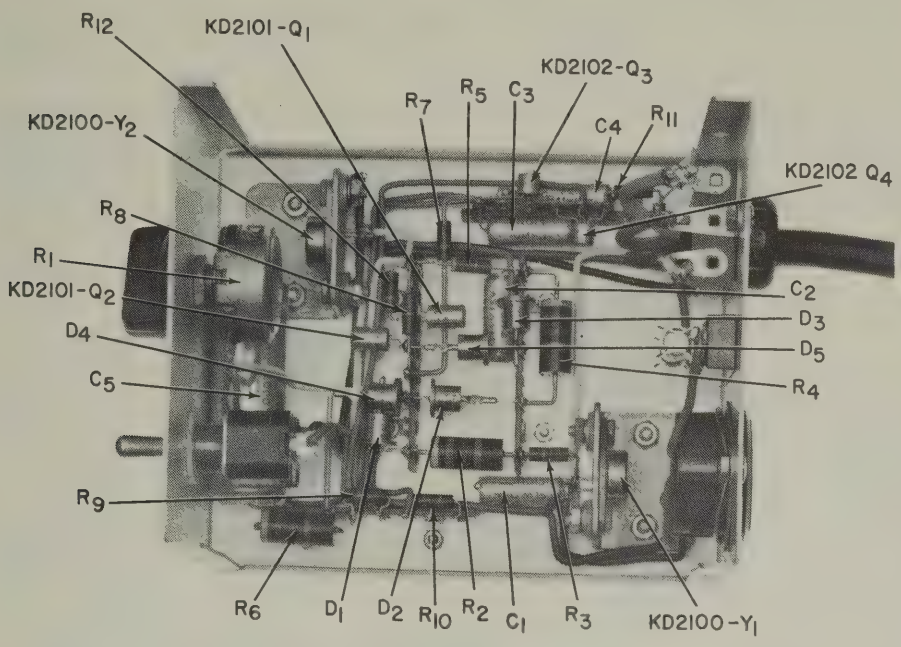


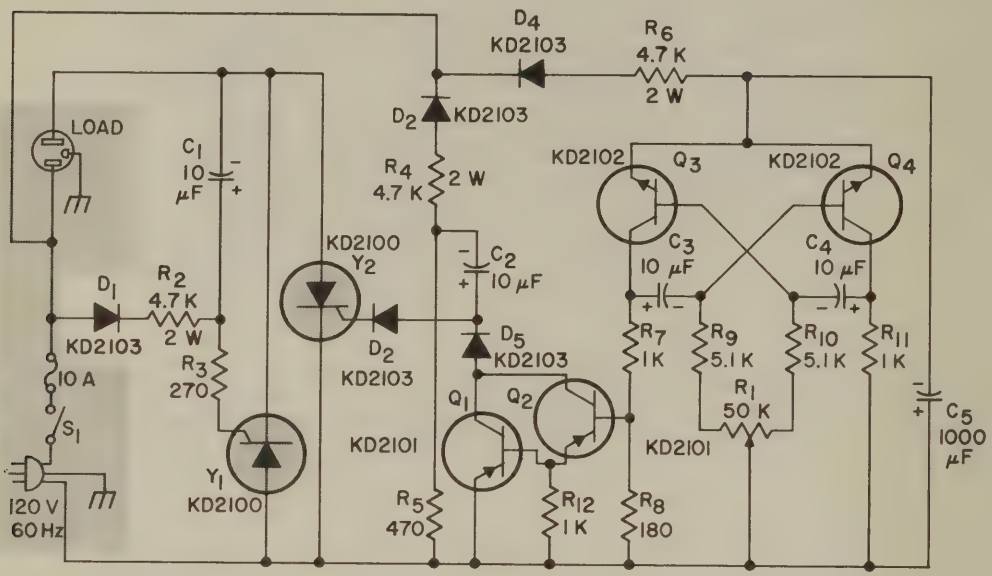
Fig. 95 — Photograph of Twin-Kit Heater Power Control (call-outs indicate components added to basic chassis).

CIRCUIT OPERATION

The schematic diagram for this circuit is shown in Fig. 96. The amount of time within each second that the unit delivers power to the load is determined by the on-off time of the KD2101 transistors Q_1 and Q_2. These transistors are connected in a Darlington arrangement to yield increased gain and are turned on and off approximately once in each second by the application of the square wave of a free-running multivibrator to their inputs. The multivibrator is composed of two KD2102 transistors; its on-off time is controlled by potentiometer R_1.

Transistors Q_1 and Q_2 conduct when an input signal is applied to the circuit and when their emitters are positive. When they conduct, the charging path for C_2 is closed through D_5, D_2, and R_4. On the following half-cycle, the charge on C_2 is applied to the gate of the SCR Y_2 and turns it on. The voltage across the load during this half-cycle is applied to the combination of D_1, R_2, and C_1, and causes the capacitor to charge. The charge on C_1 turns on Y_1 during the next half-cycle. This process repeats as long as the KD2101 transistors are conducting.

When the transistors Q_1 and Q_2 are turned off, the charging path for C_2 is opened. If this capacitor cannot charge, Y_2 cannot turn on. As a result, the circuit to the load is opened for the first half-cycle. Because there is no voltage across the load for this half-cycle, C_1 cannot charge and turn on Y_1 during the next half-cycle. Therefore, the circuit to the load remains open.



Basic chassis C (see Fig.20 for parts list)
Terminal strips, miniature, H.H. Smith No.1070 or equivalent; 2 required
C_1, C_2, C_3, C_4 = 10 microfarad, 15 volt, electrolytic
C_5 = 1000 microfarads, 15 volts, electrolytic
R_1 = potentiometer, 50,000 ohms, 2 watts, linear
R_2, R_4, R_6 = 4700 ohms, 2 watts
R_3 = 270 ohms, ½ watt
R_5 = 470 ohms, ½ watt
R_7, R_{11} = 1000 ohms, ½ watt
R_8 = 180 ohms, ½ watt
R_9, R_{10} = 5100 ohms, ½ watt
R_{12} = 1000 ohms, ½ watt

Fig. 96 — Schematic diagram of Twin-Kit Heater Power Control.

REVIEW QUESTIONS

1. In the circuits in this manual the 3-wire load receptacle is connected so that the offset connector is (not used) (grounded to the chassis) and the larger slot is connected to
   1) the load side (lower potential side) of the circuit.
   2) the line side (higher potential side) of the circuit.
   3) either side of the circuit.

   ANSWER: Fig. 43 and all other schematics

2. In the circuits in this manual, the SCR
   1) in some cases remains in conduction for two, three, or more complete cycles of input voltage depending on the setting of the potentiometer in the circuit.
   2) cannot conduct for even as much as 180° of each input half cycle of voltage.
   3) always conducts after the transistor switch conducts and for only as long as the switch remains in conduction.

   ANSWER: Page 10, Page 70

3. Photoflood lamps
   1) cannot be controlled successfully using the lamp dimmer (circuit No. 1).
   2) can be controlled without damage to the lamp or the circuit if the potentiometer is turned fully counterclockwise (minimum brightness) before the toggle switch is closed.
   3) can be controlled from cutoff to full brightness if the total load is 240 watts or less.

   ANSWER: Page 121

4. In a transistor circuit the emitter current
   1) is always equal to the sum of the base and collector current regardless of the configuration (common base, common emitter, or common collector).
   2) is equal to the difference between the base and collector currents.
   3) is greater than the collector current when an n-p-n transistor is used and less than the collector current if the transistor is a p-n-p.

   ANSWER: Page 7

5. For an n-p-n transistor the arrowhead indicates the direction of

   $\begin{matrix}\text{(conventional)}\\ \text{(electron)}\end{matrix}\left\{\begin{matrix}\text{(base)}\\ \text{(emitter)}\\ \text{(collector)}\end{matrix}\right.$ current flow.

   ANSWER: Pages 6 and 7

6. In an SCR circuit, removal of the gate current after the SCR is triggered
   1) has no effect on the conduction angle.
   2) terminates conduction between the anode and cathode of the SCR.
   3) can permanently damage the SCR if the gate current is interrupted when the anode potential is at its maximum point.

   ANSWER: Page 10

7. If the anode voltage is never allowed to become negative with respect to the cathode, and if the gate current is a steady dc of sufficient value to trigger the SCR and is always present at the gate terminal,
   1) the SCR could remain in full conduction until the power switch is opened.
   2) the SCR will stop conducting as soon as its anode potential approaches zero regardless of the gate current.
   3) the SCR could overheat and possibly become damaged.

   ANSWER: Page 11

8. In an SCR the gate-cathode path is a p-n junction and
   1) conducts gate (conventional) current in the p to n direction whenever the difference in potential across the junction exceeds the "offset" or barrier voltage.
   2) conducts current only if the potential on the anode of the SCR is high enough to cause the SCR to conduct.

3) therefore cannot conduct current unless the current is in the form of pulses.

ANSWER: Page 9

9. In the normal operation of a transistor the emitter-to-base junction is biased in a (forward) (reverse) direction and the collector-to-base junction in a (forward) (reverse) direction.

ANSWER: Page 6

10. For increasingly (larger) (smaller) gate currents the turn-on of an SCR occurs at increasingly (lower) (higher) values of (anode) (cathode) voltage until the characteristic closely resembles that of a (transistor connected in a common-emitter configuration) (a conventional rectifier).

ANSWER: Page 9

11. In circuit No.11, the model railroad and race car speed control, the load is in (parallel) (series) with the SCR and therefore current flows in the load (only when the SCR is not conducting) (when the SCR is conducting).

ANSWER: Page 83

12. In circuit No.11 the silicon diode, KD2104 (connects) (isolates) the anode of the SCR (to) (from) the potential on capacitor C_2 which allows the SCR to (conduct) (turn-off) at the end of each cycle of input voltage.

ANSWER: Page 84

13. In all the circuits in this manual the case of the SCR is at

1) ground potential.

2) anode potential and therefore is a potential shock hazard.

ANSWER: Pages 12 and 36

14. Regeneration in the two-transistor regenerative switch occurs:

1) by the application of power to either of the transistors; the other transistor plays no part in the regeneration.

2) by one transistor supplying additional base current for the other which in turn adds more base current to the first transistor; this process continues until both transistors are in full conduction.

3) when the base current in either transistor is reduced.

ANSWER: Pages 24 and 25

15. Once the two-transistor regenerative switch is triggered into full conduction, the most common method for turning it off is by

1) a higher current pulse than that which triggered it.

2) turning on the SCR.

3) reducing the voltage across the two-transistor switch (from emitter to emitter) to a value less than approximately one volt.

ANSWER: Page 25

16. Exceeding the peak reverse voltage (PRV) rating of a silicon diode

1) does no harm

2) may destroy the diode.

3) causes the PRV to become much higher.

ANSWER: Page 6

17. The resistance of the broad-area cadmium sulfide cell KD2106

1) decreases with an increase in light.

2) increases with an increase in light.

3) doesn't change with a change in light.

ANSWER: Page 38

18. A thermistor is a

1) heat sensitive resistor.

2) heat sensitive battery.

3) heat sensitive ac generator.

ANSWER: Page 39

19. In the regenerative switch test circuit, Fig.30, removal of the 1000-ohm resistor after the lamp is lighted (the "switch" is conducting)

1) will cause the lamp to go out.

2) will cause the lamp to brighten due to the increased current in the circuit.

3) will not affect the lamp; it will remain lighted.

ANSWER: Page 29

20. The solder used for all connections, except those involving thermistors, should

    1) be acid-cored.

    2) be rosin-cored.

    3) contain no flux.

ANSWER: Page 25

21. The motor speed controls and lamp dimmers in this manual vary motor speed and lamp brightness by changing

    1) the voltage across the load.

    2) the conduction time of each half cycle of voltage.

    3) the frequency of the voltage across the load.

ANSWER: Page 48

22. A capacitive network can be added to the light-operated switches and heat controls to permit these circuits to lock or latch in the switched mode. The locking or latching occurs because the capacitor in the network

    1) charges and biases the SCR's in a conducting mode.

    2) is permitted to discharge through the gates of the SCR's and thus render them conductive.

    3) holds the regenerative switch in the conducting state.

ANSWER: Page 107

23. The Heater-Power Control controls the power input to a heater by

    1) changing the voltage level across the heater element.

    2) changing the conduction time of each half-cycle of voltage.

    3) interrupting the current for a predetermined period of time during each second.

ANSWER: Page 129

24. The Twin-Kit Light-Operated Switch can be made less sensitive to small changes of light level by

    1) inserting a differential resistor in the circuit.

    2) shading the light sensor to prevent unwanted light from triggering the circuit.

    3) using the switch only with slow-acting inductive loads, such as motors.

ANSWER: Page 107

25. The motor speed controls permit good speed regulation of universal motors because

    1) they are low-impedance power supplies and have outputs that do not decrease with an increase in load.

    2) the potentiometer included in each permits the user to increase power when the motor is loaded.

    3) they are capable of sensing the increased current demand of the loaded motor and automatically adjust to conduct for a longer time in each half-cycle.

ANSWER: Page 58

26. Radio-frequency interference caused by a light dimmer can be minimized by

    1) using one of the electronic synchronous switches described in this manual.

    2) using a capacitance-inductance L-filter.

    3) plugging the lamp dimmer in the same socket as the radio.

ANSWER: Page 46

27. The anti-skip diode in the motor speed controls

    1) permits the motor to receive full voltage momentarily upon starting.

    2) protects the control components from destructive voltage transients.

    3) insures the discharge of the 1-microfarad timing capacitor at the end of each half cycle.

ANSWER: Page 54

28. When a regenerative switch is tested, false triggering can be avoided by

    1) connecting a capacitor in the test circuit.

    2) using a fresh battery with a low internal resistance.

    3) removing all connections not necessary for the test.

ANSWER: Page 35

29. The Twin-Kit Light-Operated Switch and the Twin-Kit Electronic Heat Control are insensitive to line-voltage changes because

    1) the regenerative switches used in each consist of a silicon and a germanium transistor whose characteristics cancel each other.

    2) the switching mode of each is determined by a comparison of the resistance values that set the triggering level of the regenerative switches.

    3) the diode in series with the switches acts as a voltage regulator.

ANSWER: Page 116

30. The Heater-Power Control cannot be used as a light dimmer because

    1) the circuit is not designed to handle the high initial surge currents drawn by lamps.

    2) the design of the control will not permit the inclusion of an anti-skip circuit.

    3) it will make the lamps blink rather than dim.

ANSWER: Page 128

The three Kits described in this Manual (and shown on the back cover) are available through your local RCA distributor. Additional silicon controlled rectifier assemblies (consisting of the SCR mounted on a heat sink) can also be obtained from distributors under the KD2100 number. The transistors and diodes included in the KD2105 Silicon Controlled Rectifier Experimenter's Kit are not available individually under the KD numbers, but can be replaced by the following items in RCA's universal line of semiconductor devices:

Kit Type No.	Replacement No.
KD2101	SK3004
KD2102	SK3020
KD2103	SK3016
KD2104	SK3016

Information on the cost of kits and components is also available through your RCA distributor.

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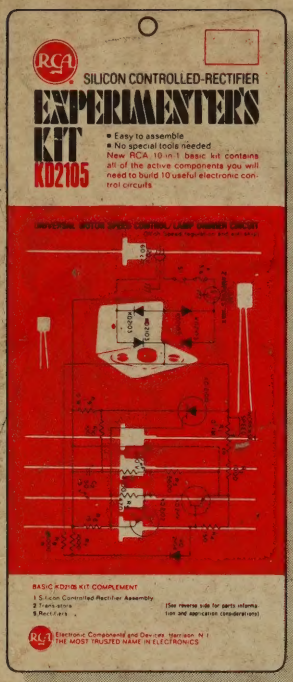
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New RCA 10-in-1 basic kit contains all of the active components you will need to build 10 useful electronic control circuits
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THE MOST TRUSTED NAME IN ELECTRONICS

With a Basic Kit containing one silicon controlled rectifier assembly, two transistors, and five rectifiers, you have the active components for building these ten useful control circuits described in the RCA SCR Experimenter's Manual KM-71:

- Electronic Timer
- Electronic Time Delay Switch
- Electronic Flasher
- Battery Charger (12 volts)
- Battery Charger (6 volts)
- Model Race Car and Railroad Speed Control
- Overload Switch
- Electronic Synchronous Switch
- Universal Motor Speed Control
- Lamp Dimmer

With two Basic Kits, you can build a Lamp Dimmer, a Battery Charger, a Motor Speed Control, an Electronic Synchronous Switch, and two Overload Switches that have a higher power-handling capability than the Single-Kit circuits. In addition, you have the active components to build these additional useful control circuits:

- Audio-Frequency-Operated Switch
- Heater-Power Control

RCA add-on Kits plus the basic Experimenter's Kit enable you to build interesting Light-Operated Switches and Electronic Heat Controls that are also described in the Manual.

ADD-ON LIGHT SENSOR
EXPERIMENTER'S KIT / KD2106
Electronic Components and Devices, Harrison, N. J.
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ADD-ON HEAT SENSOR
EXPERIMENTER'S KIT / KD2110
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